STATENS VÄXTSKYDDSANSTALT · MEDDELANDEN 11:74

SWEDISH STATE PLANT PROTECTION INSTITUTE
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With special reference to the periodicity of the adult moths

BY
EDVARD SYLVÉN

With 32 Tables and 68 Figures

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Contents

Introduction

Many tortricid species are fruit tree pests. Soon after hatching the larvae of some of them, e.g. the codling moth (*Laspeyresia* [*Cydia*] *pomonella* L.) and the red plum maggot (*Laspeyresia* [*Cydia*] *funebrana* Tr.), enter the fruits and subsequently feed solely on these. Regarding most of the species, however, both the younger and the older larvae frequently feed on the foliage. As a general name for these latter species the term *fruit leaf tortricid moths* is used in the following.

From an economic point of view it is an important fact that the fruit leaf tortricid moths, at least most of the species, do not merely injure the leaves. Long ago it was discovered that the larvae of some of the species frequently attack the flower trusses. Moreover, the larvae of several of the species cause considerable damage by feeding on the fruits.

In Sweden, as in many other parts of the world, fruit trees are often severely infested by fruit leaf tortricids. At least on apple trees the damage is frequently serious, particularly the injury caused to the crop. In this connection it can be mentioned that a total of 10,900 ungraded apple fruits originating from a total of twenty commercial orchards (located in the western half of Scania, the southernmost province of Sweden) were examined in a fruit store in the autumn of 1953. With regard to each orchard 100 apples from each of 3—10 fruit cases were picked out at random and inspected. The percentage of apples clearly showing fruit leaf tortricid injury varied greatly from the one orchard to the other, i.e. from 0 to 29. The average percentage per orchard was 9, and for each of four orchards the percentage was higher than 15.

Despite their economic interest insufficient study has been devoted to the fruit leaf tortricid moths. The life-history of several of the species has not yet been fully worked out. Regarding the relation of the different species to the physical environment but few data seem to have been published.

In Sweden the larvae of at least twelve fruit leaf tortricid species can be found feeding on apple. Since 1951 I have studied these species, chiefly in Scania at the Substation of the Swedish State Plant Protection Institute at Åkarp (for details about the location of the Substation see p. 217). These studies constitute the subject of the present paper.

Main interest was devoted to the adult moth. In order to get a better foundation for the control work in summer, a fairly close study of the annual period of flight and in this connection also of the activity of the moth was made. Light traps were operated and the relation between the catch and the physical environment was investigated. A method for the

use of light traps, suitable for determining the peak of flight of some of the species, was developed. Chiefly on the basis of the results of light trap operations an advisory service concerning the times favourable for spraying against the pests in summer was started.

Acknowledgements

To my teacher, Professor Carl H. Lindroth, head of the Entomological Department of the University of Lund, I wish to express my gratefulness and most sincere thanks for the kind interest he has taken in my work and for the sound and most valuable advice and assistance he has given me. His qualifications, both as a person and as a scientist, have been of an exceedingly helpful nature.

My deep gratitude also goes to the director of the Swedish State Plant Protection Institute, Professor Ingvar Granhall, Stockholm. He has always shown a positive attitude towards this work and has in various ways facilitated its publishing.

As already mentioned, the investigations took place chiefly at the Substation of the Swedish State Plant Protection Institute at Åkarp. I am greatly indebted to the director of the Substation, Mr John Mühlow, for all help he has given. He has provided working facilities and has always shown great understanding for my problems.

It is also a great pleasure for me to thank Dr Otto Stoy, horticultural advisor in the county of Malmöhus, for interesting talks on fruit pests and valuable assistance in connection with the financial side of my studies. On his recommendation several associations have subscribed to the investigations.

Special gratitude is due to Egon Hansson, Associate Professor, Alnarp, for his invaluable help in planning the electrical equipment of the light traps. He has also advised me in the use of thermistors.

Moreover, I tender my warm thanks to the famous specialist on Swedish *Microlepidoptera,* Dr Per Benander, Höör. He has kindly supplied me with numerous data of food plants for fruit leaf tortricids.

To Mrs Linda Kauri I am greatly indebted for invaluable technical assistance. The water-colours reproduced in figs. 1—2 and 5—6, all excellent, are her work. In addition she has, under my direction, drawn figs. 4 and 7, retouched most of my diagrams in india-ink, and taken most of the photos.

In grateful memory I hold the late Mr Sven Berdén who kindly began a critical species examination of the *Psychodidae* (*Diptera*) obtained in the light traps. His skilful and assiduous work was suddenly interrupted by his all too early death.

To Mr Jan Mattsson, who during the last few years has been occupied

with microclimatological studies at Åkarp, I tender my gratitude for good fellowship and many productive talks.

Several other persons have also shown a kind interest and been of help in my investigations. Among them I particularly wish to mention Mr Curt Fredrik Birch-Jensen, fruit grower, Mr Theodor Bogyó, technical assistant, Mr Nils-Gösta Forsberg, fruit grower, and Mr Nils Östlind, head of the School for Fruit Growing at Urshult.

Mr Carl Follin, Stockholm, has given me much valuable advice in the use of the English language. The final revision of my English has been kindly done by Mr John Edgeworth, B. A., Lund.

My uncle, Professor Nils Sylvén, has had a great influence on my scientific education, and I wish to express my deep gratitude to him. His catching enthusiasm overcomes most difficulties and has always been a model for me.

To my parents I forward my warmest thanks for their never failing solicitude. My father's thorough knowledge of forest insects deepened my interest for entomology and my mother's loving care created for me a very happy childhood.

Throughout the years of our marriage my dear wife has been an inspiration to me. For all her love and stimulating fellowship I give her my deepest thanks.

Financial support for the investigations has been received from the Swedish Agricultural Research Council, from the National Swedish Association of Commercial Fruit Growers, from the Association of Commercial Fruit Growers in the county of Malmöhus, from the corresponding Association in the county of Kristianstad, and from several parties interested in fruit pest control. To all of them I render my sincere gratefulness.

Survey of the species and their control

List of species

There have been published but few exact records of the occurrence of "fruit leaf tortricids" on apple or other fruit trees in Sweden. Although outbreaks have been mentioned several times, in most cases the data seem to be founded solely on unverified reports from the growers. Some reliable records, however, have been given by Lampa (1899, 1907), who succeeded in rearing *Argyroploce variegana* Hb., *Cacoecia rosana* L., *Cacoecia lecheana* L. and *Acroclita naevana* Hb. from larvae (or pupae) collected on apple trees in Central Sweden (south Uppland).

During the investigation at Åkarp a total of twelve species were reared from larvae found on apple in South Sweden (Scania). These species are the following:

Acleris (*Peronea, Acalla, Oxygrapha*)
  variegana Schiff.
  holmiana L.
  reticulana Ström (*contaminana* Hb.)
Cacoecia (*Archips, Tortrix*)
  podana Sc.
  xylosteana L.
  rosana L.
  lecheana L.
Pandemis (*Tortrix*)
  heparana Schiff.
  ribeana Hb.
Argyroploce (*Olethreutes*)
  variegana Hb.
Acroclita (*Rhopobota*)
  naevana Hb.
Spilonota (*Tmetocera, Eucosma*)
  ocellana F.

In Europe all the above species are known as pests. *Acl. variegana* has apparently received little, if any attention as an apple pest, but Belosel'skaya (1925) has discussed an outbreak of this species on apricot and plum in Leningrad. *Acl. holmiana* has been recorded as a pest of pear and apple in France (Lesne 1915); *Acl. reticulana* a pest of e. g. apple in France (Paillot 1935) and Great Britain (Hey and Massee 1934). *Cac. xylosteana* has been reported a pest of pear and apple in Spain (Alfaro 1950); *Cac. rosana* a serious apple pest in e. g. Switzerland (Baggiolini 1956). *Acr. naevana* has

caused much damage to apple in Italy (Lucchese 1940). The remaining six species — *Cac. podana* and *Cac. lecheana, Pand. heparana* and *Pand. ribeana, Arg. variegana* and *Spil. ocellana* — have all been recognized pests of apple and other fruit trees, e. g. in Great Britain (Hey and Massee 1934).

Great attention has been paid in Central Europe to *Adoxophyes* (*Capua*) *orana* F. R. (*reticulana* Hb.), a fruit leaf tortricid which has been a serious apple pest during recent years in many countries, e. g. in Belgium (Soenen [1947]), Holland (de Jong 1951), Great Britain (Groves 1951, 1952) and Switzerland (Bender 1953). Also *Cacoecia crataegana* Hb. is a fruit leaf tortricid which has been found to be an apple pest in several countries, e.g. in Great Britain (Hey and Thomas 1933). These two species are recorded also from Sweden, where they, however, have apparently not been noticed as pests.

Other fruit leaf tortricids are *Cacoecia sorbiana* Hb. and *Pammene rhediella* Cl., both of which have been reared in Great Britain from material collected on apple trees (Hey and Massee 1934); also *Pandemis corylana* F., reared in Switzerland from larvae found on fruit trees (Bender 1953), and *Exapate congelatella* Cl., the larvae of which have been observed on e.g. apple trees in Finland (Vappula 1933). In Sweden these four species, although widely distributed in the southern and central parts of the country, seem to be of little economic importance.

The following accounts and discussions contain various data on fruit leaf tortricids. Unless otherwise stated, only the twelve species which were reared at Åkarp from larvae found on apple are considered.

Geographical distribution

Table 1 shows in which Swedish provinces the different species have been discovered. *Spil. ocellana* was captured in Södermanland (Mariefred) in connection with the present investigation and there are no previous reports of its existence in this province. Otherwise all data in the table are taken from the distribution lists of Benander (1946, 1953).

As can be seen, the species are widely distributed in Götaland (South Sweden) and Svealand (Central Sweden). In addition, all species except *Cac. lecheana* and *Spil. ocellana* are recorded from Norrland (North Sweden). However, from the inland provinces of this latter area only three of the species are reported, viz. *Pand. ribeana* from Jämtland and Lapland (Åsele Lappmark and Lycksele Lappmark), *Cac. podana* from Lapland (Lycksele Lappmark) and *Cac. rosana* from Lapland (Lycksele Lappmark).

All species are recorded from Finland, Norway and Denmark (Benander 1946); also from many other countries in Europe, e.g. from Great Britain

Table 1. Distribution data. Sweden.

● = one or more records. — = no record.

	Götaland (South Sweden)										Svealand (Central Sweden)						Norrland (North Sweden)								
	Scania	Blekinge	Halland	Småland	Öland	Gotland	Östergötland	Västergötland	Bohuslän	Dalsland	Närke	Södermanland	Uppland	Västmanland	Värmland	Dalarna	Gästrikland	Hälsingland	Medelpad	Härjedalen	Jämtland	Ångermanland	Västerbotten	Norrbotten	Lapland
Acl. variegana	●	—	●	●	●	●	—	●	●	—	●	●	●	—	●	●	—	●	●	—	—	●	●	●	—
,, *holmiana*	●	●	●	●	●	●	●	●	●	●	—	●	●	—	●	●	—	—	●	—	—	●	—	—	—
,, *reticulana*	●	—	—	●	●	●	●	●	●	—	—	●	●	—	—	●	—	—	—	—	—	●	—	—	—
Cac. podana	●	●	●	●	●	●	●	●	●	●	●	●	●	●	—	—	—	—	—	—	—	—	—	—	●
,, *xylosteana*	●	●	●	●	●	●	●	●	●	—	—	●	●	—	●	—	—	—	—	—	—	●	—	—	—
,, *rosana*	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	—	●	●	—	—	●	●	—	●
,, *lecheana*	●	●	●	●	●	●	●	●	●	—	—	●	●	—	●	●	—	—	—	—	—	—	—	—	—
Pand. heparana	●	●	●	●	●	●	●	●	●	●	—	●	●	●	●	●	—	—	—	—	—	●	●	●	—
,, *ribeana*	●	●	●	●	●	●	●	●	●	●	—	●	●	●	●	●	—	●	●	—	●	●	●	●	●
Arg. variegana	●	●	●	●	●	●	●	●	●	●	—	●	●	—	●	●	—	—	—	—	—	●	—	●	—
Acr. naevana	●	●	●	●	●	●	●	●	—	●	—	●	●	●	●	●	—	—	—	—	—	●	●	●	—
Spil. ocellana	●	●	—	●	●	●	●	●	●	—	—	●	●	—	—	●	—	—	—	—	—	—	—	—	—

(Meyrick [1927]), France (de Joannis 1908), Belgium (de Crombrugghe de Picquendale 1906), USSR (Albrecht 1882, Alpheraki 1876, 1908, Krulikowsky 1908) and Italy (Staudinger and Rebel 1901, Sarra 1917, Silvestri 1922, Amsel 1936). At least ten of the species (all except *Pand. heparana* and *Acr. naevana*) are mentioned from Asia Minor (Staudinger [1880], Kennel 1908—1921, Meyrick [1927]); some of them also from other parts of Asia — e.g. *Cac. podana, Cac. xylosteana, Pand. heparana, Pand. ribeana, Acr. naevana* and *Spil. ocellana* from Siberia and Japan (Meyrick [1927]). Moreover, at least one of the species, *Acl. variegana*, is recorded from North Africa (Algeria; cf. Chrétien 1917).

Finally, several of the species are stated to occur in North America, viz. *Acl. variegana, Cac. rosana, Arg. variegana, Acr. naevana* and *Spil. ocellana* (Forbes 1923, Meyrick [1927]). One additional species, *Cac. podana,* was on one occasion (in 1920) found in USA in a cargo of *Rosa* from Holland (Sasscer 1921).

Identification keys

The following synopsis is intended mainly for workers in the field of economic entomology. The figures showing the wing expanse are according to Benander (1950). Otherwise all data are founded on or verified by my own observations and examinations.

The key for the identification of the adult moths includes all species reared at Åkarp. The remaining keys include all species except *Acl. variegana*. Unfortunately I have only been able to study this latter species in the adult stage.

Detailed description of the adult moths can be found in several works, e.g. in Kennel's monograph on palaearctic tortricids (1908—1921). The male and the female genitalia of the different species have been drawn by Pierce and Metcalfe (1922).

The egg and/or the larva of several of the species have been briefly described by Soenen ([1947]), Alfaro (1950) and others. Much valuable information of the characteristics of the early stages (egg, larva, pupa) in *Cac. podana* has been given by Hey and Thomas (1934). The early stages in *Arg. variegana* have been described by Sarra (1917), in *Acr. naevana* by Lucchese (1940), in *Spil. ocellana* by many authors, e.g. by Sanders and Dustan (1919), Silvestri (1922) and Porter (1924). Figures showing some of the characteristics of the larva in *Pand. ribeana* are included in a paper by Trägårdh (1915). A comparison of the pupae of *Arg. variegana* and *Spil. ocellana* has been made by Ripper (1929).

The adult moths

The wing expanse (according to Benander; cf. above) is as follows: 12—15 mm. (*Acr. naevana, Acl. holmiana*), 13—17 (*Spil. ocellana*), 13—18 (*Acl. variegana*), 14—19 (*Acl. reticulana*), 16—23 (*Cac. xylosteana, Pand. ribeana*), 17—21 (*Arg. variegana*), 17—24 (*Pand. heparana*), 18—22 (*Cac. lecheana, Cac. rosana*) and 19—26 (*Cac. podana*).

Regarding several of the species the colour, particularly that of the head, the thorax and the fore wings, varies greatly. In *Spil. ocellana*, for example, the basic colour of the upper side of the fore wings ranges from white to dark-grey; in *Acl. reticulana* from light yellow to rusty brown.

Among easily recognizable male characteristics the following can be mentioned: in the males of the four *Cacoecia* species the front margin of the fore wings is partially folded over, forming a so-called costal fold; the antennae in the males of the two *Pandemis* species, as well as in the males of *Spil. ocellana*, show a cavity near the base; the males of *Acr. naevana* are distinguished by a broad black fascia running near the front margin on the underside of the hind wings.

Mainly wing characteristics are discussed in the following key. The upper side of the wings is referred to in all cases.

Key

1. Fore wings with a triangular, yellowish brown to black spot near outer part of inner margin .... *Spilonota ocellana* Fig. 2:R

— No such spot 2

2. Fore wings with a conspicuous white spot at middle of front margin .... *Acleris holmiana* Fig. 1:C

— No such spot 3

3. Fore wings with several prominent scale tufts ...... *Acleris variegana* Fig. 1:A

— No scale tufts 4

4. Fore wings white or yellowish white (sometimes with a tinge of red) towards tip .... *Argyroploce variegana* Fig. 2:N

— Fore wings *not* white or yellowish white towards tip 5

5. Fore wings with several paired, white or yellowish white striae at front margin .... *Acroclita naevana* Fig. 2:P

— No such striae 6

6. Hind wings greyish white .... *Acleris reticulana* Fig. 1:B

— Hind wings dark-grey, greyish brown or brown, sometimes yellow or orange along front margin and towards tip 7

7. Distance between head and tip of labial palpus longer than two thirds of length of head 8

— Distance between head and tip of labial palpus shorter than two thirds of length of head 9

8. Basic colour of fore wings reddish brown or dark-brown .... *Pandemis heparana* Fig. 1:D

— Basic colour of fore wings yellowish brown or ochrous brown .... *Pandemis ribeana* Fig. 1:E

9. Fore wings with shining lead-grey bands and spots but otherwise without markings .... *Cacoecia lecheana* Fig. 1:F

— Fore wings sometimes with shining lead-grey areas but then always with distinctly defined, brown or black markings 10

10. Median band of fore wings with a tooth-shaped, black spot on its outer side .... *Cacoecia xylosteana* Fig. 1:G

— No such spot 11

11. Fore wings with a black spot at tip .... *Cacoecia podana* Fig. 2: L and M

— No such spot .... *Cacoecia rosana* Fig. 2: H and K

Fig. 1. Adults of fruit leaf tortricids. × 2 ½. — A. *Acleris variegana*, ♂. — B. *Acleris reticulana*, ♂. — C. *Acleris holmiana*, ♂. — D. *Pandemis heparana*, ♂. — E. *Pandemis ribeana*, ♀. — F. *Cacoecia lecheana*, ♀. — G. *Cacoecia xylosteana*, ♀.

Fig. 2. Adults of fruit leaf tortricids. × 2 1/2. — H. *Cacoecia rosana*, ♂. — K. Ditto, ♀. — L. *Cacoecia podana*, ♂. — M. Ditto, ♀. — N. *Argyroploce variegana*, ♂. — P. *Acroclita naevana*, ♀. — R. *Spilonota ocellana*, ♂.

The eggs

The eggs are more or less plano-convex in shape, flattened, with oval or almost circular outline. In *Acl. reticulana* the size averages about 0.8×0.5 mm., in *Spil. ocellana* about 0.9×0.7 mm. Roughly estimated, the size in *Acl. holmiana* is equal to that in *Acl. reticulana*, the size in each of the remaining species being equal to that in *Spil. ocellana.*

Regarding the colour characteristics, only *freshly laid eggs* are considered in the following key. The data referring to the position of the eggs on the host plant are founded on observations made on apple.

I have not yet succeeded in distinguishing the eggs of all the species. Further studies are to be desired, since much still remains to be investigated, e.g. regarding the external structure of the egg shell.

Key

1\. On surface of leaves 2
— On surface of bark on stem or branches 3

2\. Larger or smaller egg batches — with the eggs overlapping one another like slates on a roof; egg yellowish green .... *Pandemis heparana*
Pandemis ribeana
Cacoecia lecheana
Cacoecia podana
Fig. 3:A
— Singly deposited (normally); egg transparent or semi-transparent, whitish .... *Argyroploce variegana*
Spilonota ocellana
Fig. 3:C

3\. Larger or smaller egg batches — with the eggs overlapping one another like slates on a roof 4
— Singly deposited (normally) 5

4\. Egg greyish green .... *Cacoecia rosana*
Fig. 3:B
— Egg violet brown .... *Cacoecia xylosteana*

5\. Egg transparent or semi-transparent, whitish .... *Acroclita naevana*
Fig. 3:D
— Egg yellowish green .... *Acleris reticulana*
Acleris holmiana

The full-grown larvae

The larva reaches a length of about 10—12 mm. (*Acr. naevana, Acl. holmiana*), 10—13 (*Spil. ocellana*), 12—14 (*Acl. reticulana*), 14—17 (*Arg. variegana*), 16—23 (*Cac. podana*) and roughly 15—20 mm. (each of the remaining species).

The body consists of a head, three thoracic and ten abdominal segments.

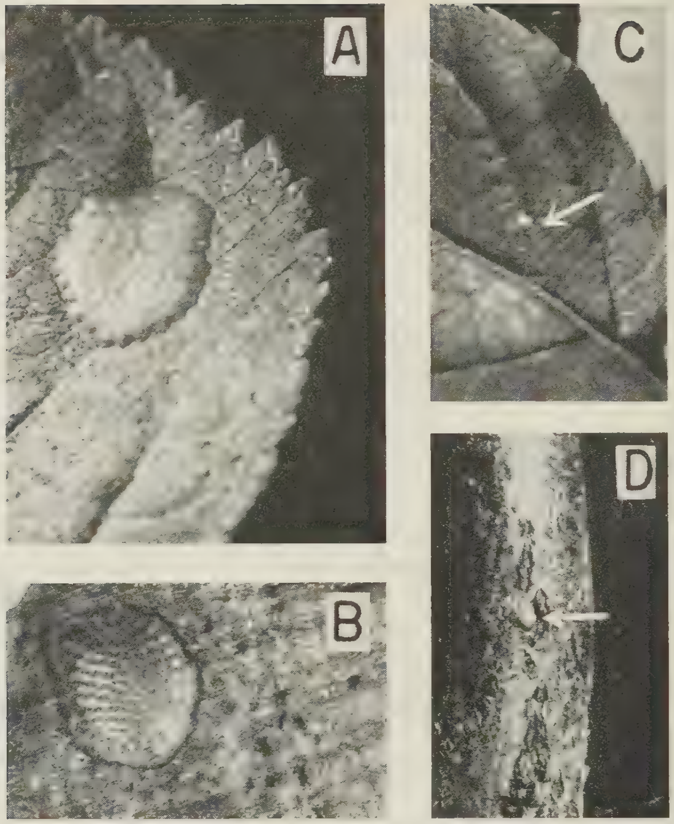

Fig. 3. Eggs of fruit leaf tortricids. × 4 approx. — A. *Cacoecia podana,* egg batch on an apple leaf. — B. *Cacoecia rosana,* egg batch on bark of apple. — C. *Spilonota ocellana,* egg on an apple leaf. — D. *Acroclita naevana,* egg on bark of apple.

The head capsule is almost entirely composed of the epicranium. This is divided by sutures (the colour of which is neglected in the following key) into five parts: the triangular shaped frons, the two elongated and narrow adfrontals and the two spherical epicranial lobes (cf. Fracker 1915).

On the dorsum of the first thoracic segment there is a prominent plate, the prothoracic shield, and on the dorsum of the last abdominal segment a similar plate, the suranal shield.

There are setae on the head, on the two shields mentioned above, many also on other parts of the body. The latter setae arise from distinctly defined, more or less wart-like structures, called tubercles in the key. Sometimes the tubercles are dark, sometimes pale with or without dark rings or areas around the setae.

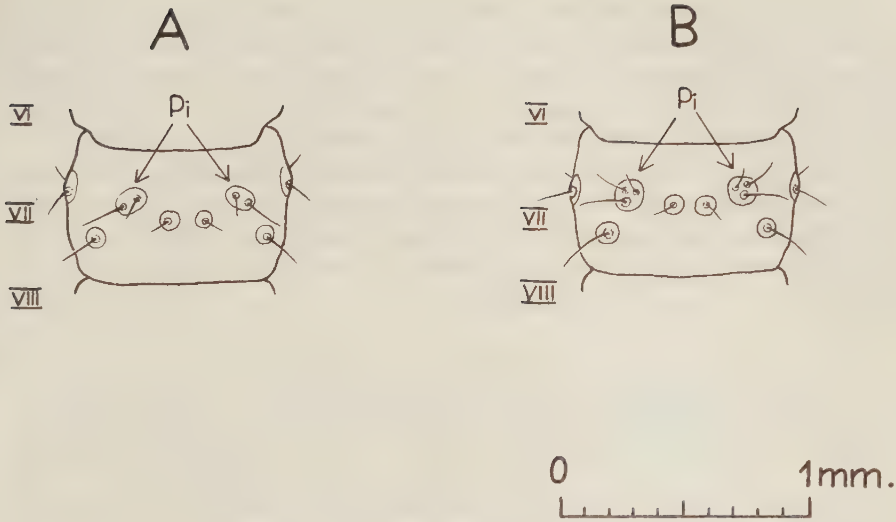

Fig. 4. Ventral view of seventh abdominal segment in a last instar larva of *Acleris reticulana* (A) and in a last instar larva of *Cacoecia rosana* (B). — Pi = the setal groups called the Pi groups in the key.

Two groups of setae are discussed in the key. They are termed according to a system proposed by Fracker (1915). One of them is the Pi group on the left half, the other the Pi group on the right half of the seventh abdominal segment. They are situated on the venter of the body (see fig. 4).

In most of the species there are great individual variations in the general body colour, in the colour of the prothoracic shield, the suranal shield etc. It is also to be noted that there are, at least in some of the species, individual variations in the arrangement of the setae.

It is possible that the setal characteristics used in the key are not absolutely constant in any of the species.

In this connection it can be mentioned that the number of setae in the two Pi groups on the seventh abdominal segment was determined in a total of 94 last instar larvae (*Cac. lecheana* only 2 larvae, *Cac. podana* and *Arg. variegana* 3 larvae each, *Pand. ribeana* 4 and the seven remaining species from 9 to 15 larvae each). All but three of the larvae showed either two (*Acleris, Cac. lecheana, Argyroploce, Acroclita, Spilonota*) or three (*Cac. xylosteana, Cac. podana, Cac. rosana, Pandemis*) setae in each of the two Pi groups. In one larva (*Pand. ribeana*) there were three setae in one but only two setae in the other Pi group. Two larvae (*Acl. reticulana, Acroclita*), finally, showed two setae in one but only one seta in the other Pi group.

The three last-mentioned larvae had perhaps lost one seta in one of the two Pi groups during the period between the last moult and the examination. These larvae, like the remainder of those discussed above, were not examined until full-grown or almost full-grown.

When the larva has stopped feeding, its body gradually shrinks and more or less changes in colour. In *Cac. xylosteana,* for example, the general body colour alters from grey to green, in *Spil. ocellana* from reddish brown to pale brownish grey. No notice of the colour of the larva in the different species during this period preceding the pupation is taken in the key.

I am not sure that there are constant, external, distinguishing characteristics between the larvae of the two *Acleris* species, between the larvae of *Cac. xylosteana, Cac. podana* and *Cac. rosana,* and between the larvae of the two *Pandemis* species. Continued studies on the larval characteristics of these species are much to be desired.

Key

1. At least major part of each tubercle blackish brown or black; general body colour lighter or darker green; epicranium blackish brown or black .... *Argyroploce variegana* Fig. 6:M

— Tubercles on lateral parts of first thoracic segment varying in colour; at least major part of each of remaining tubercles of body concolorous with or lighter than major part of body 2

2. Major part of dorsal half of body occupied by a distinctly defined fascia, deep olive green or deep bluish green in colour (sometimes with a tinge of red); major part of rest of body yellow, greenish yellow or light green; epicranium largely pale yellowish brown or pale greyish brown, more or less transparent .... *Cacoecia lecheana* Fig. 5:A

— Major part of dorsal half of body sometimes occupied by a distinctly defined, dark fascia, but epicranium then entirely dark-brown or black, not transparent 3

3. Epicranium largely or entirely transparent or semi-transparent, without distinct colour; general body colour yellow or lighter or darker green .... *Pandemis heparana* Fig. 5:F
Pandemis ribeana Fig. 5:G and H

   Note: Epicranium generally almost entirely transparent or semi-transparent in *Pand. heparana;* usually to a large degree dark, or richly dark-spotted in *Pand. ribeana*

— Epicranium distinctly coloured; entirely reddish brown (sometimes with darker spots), dark-brown or black 4

4. With two setae, both situated on same tubercle, in each of the two Pi groups of seventh abdominal segment (see fig. 4:A) 5

— With three setae, all situated on same tubercle, in each of the two Pi groups of seventh abdominal segment (see fig. 4:B) .... *Cacoecia xylosteana* Fig. 5:B
Cacoecia podana Fig. 5:C and D
Cacoecia rosana Fig. 5:E

Fig. 5. Full-grown larvae of fruit leaf tortricids, dorsal and side view. $\times 2\,^1/_2$. — A. *Cacoecia lecheana.* — B. *Cacoecia xylosteana.* — C—D. *Cacoecia podana.* — E. *Cacoecia rosana.* — F. *Pandemis heparana.* — G—H. *Pandemis ribeana.*

Fig. 6. Full-grown larvae and pupae of fruit leaf tortricids; larvae dorsal and side view, pupae dorsal and ventral view. All × 2 ½. — K. *Acleris holmiana.* — L. *Acleris reticulana.* — M. *Argyroploce variegana.* — N. *Acroclita naevana.* — P. *Spilonota ocellana.* — R. *Acleris reticulana,* ♂. — S. *Cacoecia podana,* ♀. — T. *Acroclita naevana,* ♂.

Note: General body colour grey in *Cac. xylosteana;* usually lighter or darker green, sometimes possibly grey in *Cac. podana* and *Cac. rosana*

5. Epicranium entirely or chiefly light or bright reddish brown .... *Acleris holmiana* Fig. 6:K *Acleris reticulana* Fig. 6:L

Note: General body colour yellow with or without a tinge of green in *Acl. holmiana;* sometimes yellow, usually green in *Acl. reticulana.* Prothoracic shield, at least in most cases, largely blackish brown or black in *Acl. holmiana;* usually entirely light brown, more or less transparent in *Acl. reticulana*

— Epicranium entirely blackish brown or black 6

6. Major part of body reddish brown .... *Spilonota ocellana* Fig. 6:P

— Major part of body yellow or lighter or darker green *Acroclita naevana* Fig. 6:N

The pupae

The body length in the pupa is about 5—6 mm. (*Acr. naevana, Acl. holmiana*), 6—7 (*Spil. ocellana*), 7—8 (*Acl. reticulana*), 8—9 (*Arg. variegana*), 10—12 (*Cac. podana*) and 9—11 mm. (each of the remaining species). In all the species the general colour of the empty pupal case is lighter or deeper brown.

Only abdominal characteristics are discussed in the following key. There are a total of ten abdominal segments. The anus is slit-like and situated on the venter of the last segment. In most of the species this segment shows a well-developed prolongation known as the cremaster (see e.g. Mosher 1916). By examining the pupa (or the empty pupal case) from the side, the length of the cremaster can be easily determined.

Yet, I have found no definite characteristics to distinguish the pupae of *Cac. xylosteana, Cac. podana* and *Cac. rosana.*

Key

1. Cremaster present 2

— Cremaster absent 8

2. Cremaster with several hooked setae 3

— Cremaster without hooked setae .... *Acleris reticulana* Fig. 6:R; fig. 7:A

3. Last segment with hooked setae on cremaster only 4

— Last segment with hooked setae also in front of cremaster (on venter near anal slit) 7

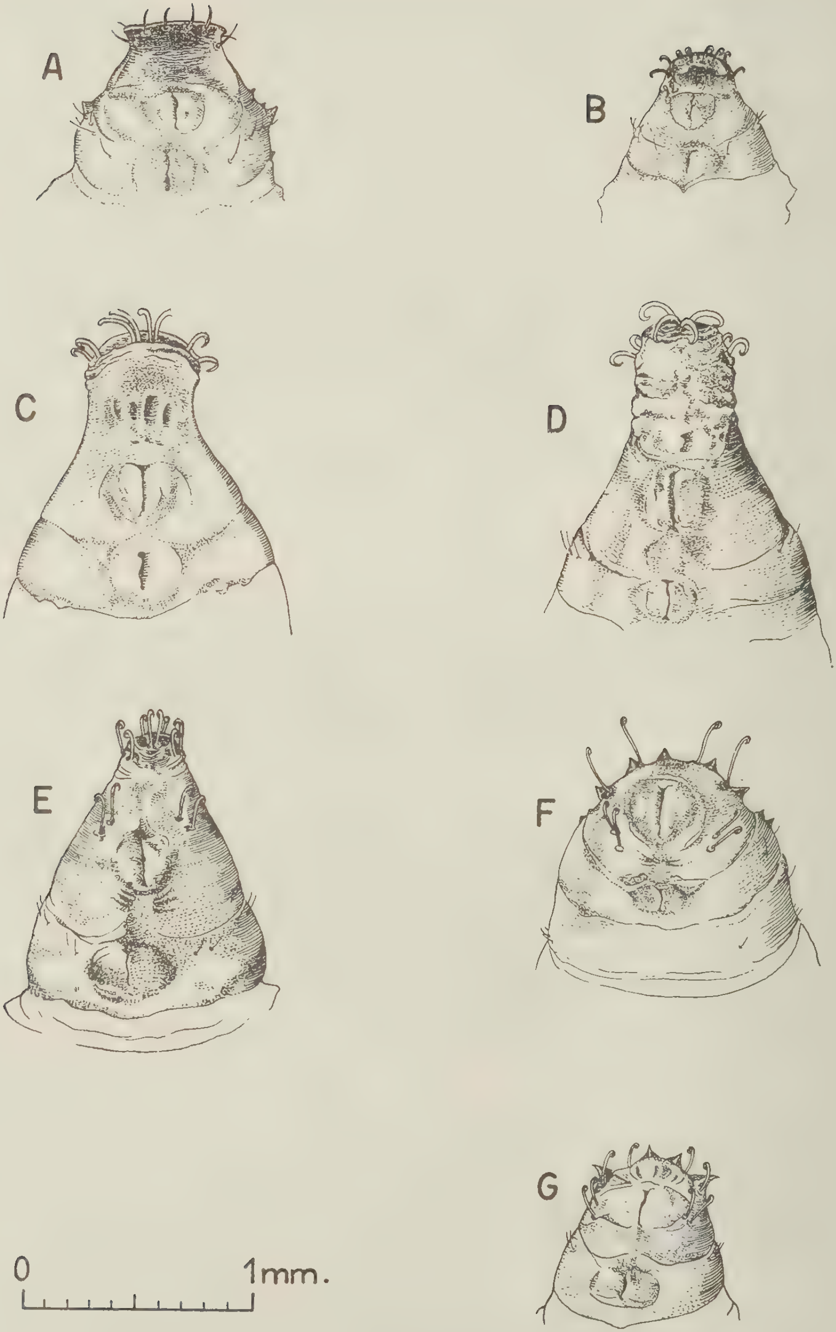

Fig. 7. For explanation see p. 157.

4. With four prominent, pouchlike cavities — one pair on dorsum of second and one pair on dorsum of third abdominal segment *Cacoecia xylosteana*
Cacoecia rosana
Cacoecia podana
Fig. 6:S

— Without such cavities 5

5. Frontal half of dorsum of second abdominal segment without well-developed spines; instead with a transverse row of straight, longitudinal ridges; anterior end of each ridge blunt, posterior end blunt, or with a fine, inconspicuous point .... *Cacoecia lecheana*

— Frontal half of dorsum of second abdominal segment without straight ridges; instead with a transverse row of well-developed, more or less conical spines 6

6. Cremaster about as wide as long .... *Pandemis heparana*
Fig. 7:C

— Cremaster considerably longer than wide .... *Pandemis ribeana*
Fig. 7:D

7. Hooked setae near anal slit of about same length as those on cremaster ... . *Argyroploce variegana*
Fig. 7:E

— Hooked setae near anal slit considerably shorter than those on cremaster .... *Acleris holmiana*
Fig. 7:B

8. Last segment with a gibbous elevation behind anal slit .... *Acroclita naevana*
Fig. 6:T; fig. 7:G

— Last segment without elevation behind anal slit...... *Spilonota ocellana*
Fig. 7:F

Food plants

A number of food plant data are to be found in table 2. Many of them are according to a list which the Swedish lepidopterologist, Dr Per Benander, Höör, has kindly given me and which is based on his rearings. The remaining figures are according to rearings made at Åkarp in connection with the present investigations, or according to authentic records given by Sorhagen (1882), Deakin (1914) or Hey and Massee (1934). Additional data of food plants have been published, but in many cases it is difficult to decide whether they are reliable or not.

Fig. 7. Ventral view of posterior part of abdomen in male pupae. — A. *Acleris reticulana*. — B. *Acleris holmiana*. — C. *Pandemis heparana*. — D. *Pandemis ribeana*. — E. *Argyroploce variegana*. — F. *Spilonota ocellana*. — G. *Acroclita naevana*.

Note: With regard to the external characteristics of the last abdominal segment there are only slight, if any differences between the pupa of the four *Cacoecia* species and the pupa of *Pandemis ribeana*.

Table 2. Food plants of larvae. Circle, column A = moth reared by Sylvén from larva found feeding on recorded plant species or plant genus. Circle, column B = ditto by Benander. Circle, column C = literature record; cf. text.

	Acl. variegana			*Acl. holmiana*			*Acl. reticulana*			*Cac. podana*			*Cac. xylosteana*			*Cac. rosana*			*Cac. lecheana*			*Pand. heparana*			*Pand. ribeana*			*Arg. variegana*			*Acr. naevana*			*Spil. ocellana*		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Larix																																			●	
Populus										●	●					●	●					●														
Salix											●						●															●				
Carpinus																●																				
Alnus																							●												●	
Betula											●									●			●			●										
Quercus											●	●			●					●	●					●	●									●
Ulmus														●			●																			
Ribes																	●	●				●				●										
Crataegus					●			●	●			●															●	●	●	●						●
Cotoneaster		●			●												●																			
Prunus avium and/or P. cerasus												●									●									●						●
Prunus domestica									●			●										●					●		●					●		●
„ spinosa		●			●			●									●																			
Pyrus communis									●			●				●	●				●			●			●			●			●			●
„ malus	●			●	●		●	●	●	●		●	●			●	●		●		●	●		●	●	●	●	●	●	●	●			●	●	●
Rosa		●								●			●			●	●					●	●		●											
Rubus												●					●																			●
Sorbus					●											●	●												●							
Pelargonium											●																									
Euonymus														●																						
Rhamnus																	●						●													
Tilia														●																						
Ledum																										●										
Vaccinium			●								●																					●				
Fraxinus																				●			●													
Lonicera											●															●										
Rumex											●																									
Medicago																	●																			
Impatiens																										●										
Lysimachia																							●													
Achillea																	●																			

As can be seen in the table, the food plant range is wide. Several of the species, at least, attack both ligneous and herbaceous plants.

Annual life-cycle

The bionomics of *Arg. variegana* and *Spil. ocellana* have been studied in detail by many authors, e. g. in Nova Scotia by Sanders and Dustan (1919) and in Switzerland by Wiesmann (1927). The life-history of some of the other species has also been carefully worked out. *Acr. naevana* has been thoroughly studied in Italy by Lucchese (1940), *Cac. podana* in Great Britain by Hey and Thomas (1934), *Cac. rosana* in France by Guennelon (1955) and in Switzerland by Baggiolini (1956). An account of the life-history of *Cac. xylosteana* in Spain has been given by Alfaro (1950).

Little exact information of the life-history of *Cac. lecheana* seems to be available. The same is true of the two *Pandemis* and the three *Acleris* species.

The life-history and the habits of the moths on apple in South Sweden (Scania) are briefly discussed below. All the species except *Acl. variegana* (cf. p. 141) are dealt with. The data are mainly founded on observations made at Åkarp.

Frequently two or more species are enumerated in sequence in the following survey. They are then, as nearly as possible, chronologically arranged, according as they appear in the adult stage in the season. The earliest species in this respect is *Cac. lecheana* (peak of flight in the first half or in the middle of June). The latest species is *Acl. reticulana* (peak of flight in August or September). The annual flight of several of the species is considered in detail in a subsequent chapter (p. 180 ff.).

It is not proved by my studies that the different species have more than one flight, i.e. fly in more than one generation, a year. The results of light trap experiments, however, indicate that there are sometimes two flights in *Cac. podana* (cf. fig. 39 [p. 226]). A more or less regular secondary emergence can perhaps also occur in some of the remaining species, e.g. in *Spil. ocellana*. De Jong (1951) states that in Holland a second flight of the latter species sometimes takes place.

The second flight, if present, is always poor in individuals compared with the first flight, and of little significance from an economic point of view. In the continued discussion all the species are regarded as having but one generation annually.

The larvae of the different species show no tendency to keep together in colonies. Usually they are found singly, between leaves webbed-together or in other sheltered positions.

According to their *hibernation habits* the species can be divided into two

Table 3. Egg incubation on leaves on apple stocks, Åkarp 1952.

Note: The studies took place in a shady place out-of-doors. The stocks were grown in pots standing on the ground. They were examined in period 9 a. m.—5 p. m., usually once a day. It is supposed in the table that oviposition and hatching only occurred at 6 p. m.

The figures in the last column indicate the temperature conditions about 50 m. away from the stocks, in the screen shown in fig. 55. Each figure is calculated on the basis of the hourly temperatures recorded by the thermograph mentioned on p. 260.

	Stock(s) no(s).	Date eggs laid	Period from oviposition until first eggs hatched	
			Length in days	Average temp. in °C
Pandemis ribeana	1	June 30	13	17·3
	2	„ 30	15	17·[illegible]
	3	July 2	12	17·3
	4	„ 2	16	16·3
	5	„ 2	14	16·2
	6	„ 3	17	16·[illegible]
	7	„ 7	15	15·[illegible]
Cacoecia podana	8	July 3	17	16·[illegible]
	9	„ 3	19	16·6
	10—12[1]	„ 4	18	16·[illegible]
	13—14	„ 5	18	16·[illegible]
	15	„ 5	19	16·6
	16	„ 6	16	15·9
	17	„ 8	20	15·[illegible]
	18	„ 8	21	15·[illegible]
	19—20	„ 8	22	15·[illegible]
	21	„ 9	21	15·6
	22—23	„ 9	22	15·[illegible]
	24	„ 9	23	15·1
	25	„ 10	21	14·9
	26—29	„ 10	22	14·9
	30	„ 14	22	15·1
	31	„ 16	20	15·1
	32	„ 23	19	16·0
Pandemis heparana	33	July 9	21	15·0
	34	„ 10	21	14·9
	35	„ 17	20	15·3
	36	„ 23	19	16·[illegible]
	37—38	„ 24	18	16·0
	39	„ 28	15	16·9
	40	„ 29	15	17·2
	41	„ 29	16	17·2
	42	„ 31	14	17·1
	43	Aug. 5	15	16·6
Spilonota ocellana	44—47	Aug. 5	16	16·5
	48—49	„ 5	17	16·3
	50	„ 6	15	16·3
	51—53	„ 6	16	16·2
	54	„ 14	21	14·8
	55	„ 14	24	14·4
	56—57	„ 15	23	14·3
	58	„ 18	26	13·5
	59	„ 19	27	13·2
	60	„ 21	39	12·2
	61	„ 22	33	12·3

[1] On each of these stocks first eggs hatched in 18 days. Similarly, on each of the stocks nos. 13—14 first eggs hatched in 18 days, on each of the stocks nos. 19—20 in 22 days, etc.

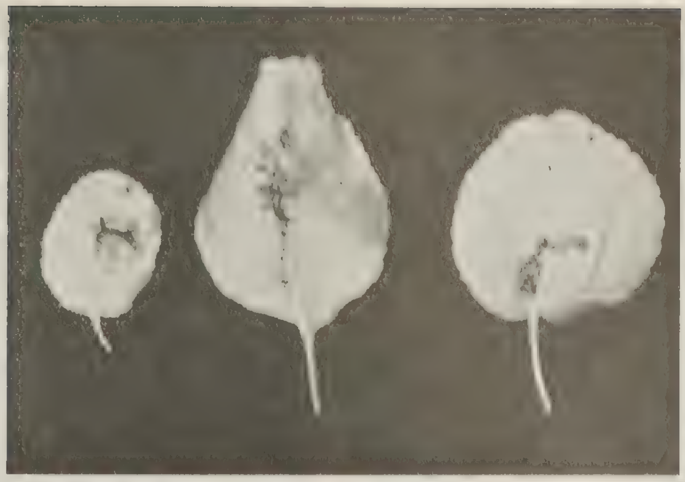

Fig. 8. Apple leaves injured by young larvae of *Spilonota ocellana*. Nat. size.

groups: (1) species hibernating as immature larva and (2) species hibernating in the egg stage. The two groups are considered separately below.

1. Species hibernating as immature larva. There are six species in this group: *Cac. lecheana, Arg. variegana, Pand. ribeana, Cac. podana, Spil. ocellana* and *Pand. heparana*. The following data apply to each of these species, unless otherwise stated.

Normally the eggs are laid singly (*Arg. variegana, Spil. ocellana*) or in batches (*Cac. lecheana, Pand. ribeana, Cac. podana, Pand. heparana*) on the leaves (cf. p. 147).

The total number of eggs deposited by a single female is extremely variable. The highest figures recorded at Åkarp (in moths kept confined outdoors on apple stocks) are in round numbers: > 120 (*Cac. lecheana*), > 150 (*Arg. variegana*), 310 (*Pand. ribeana*), 330 (*Cac. podana*), 250 (*Spil. ocellana*), > 240 (*Pand. heparana*).

Generally, the egg hatches in about two à three weeks. Data showing the incubation period in some eggs kept under observation at Åkarp are given in table 3.

Before entering the winter quarter the larva feeds for some time on the foliage or the fruit. Often the young larva[1] spins a web, and begins to feed, on the underside of a leaf, usually next to the midrib or one of its larger branches. Frequently it binds two leaves together and feeds between them.

[1] The larva is considered to be young up to the beginning and old from the end of the resting period in the winter quarter.

Fig. 9. Left. Leaf attached to fruit by a young larva of *Spilonota ocellana* Right. Same fruit with leaf removed to show injury caused by the larva. ¾ nat. size.

Also when feeding on the fruit it conceals itself, e.g. beneath a leaf which it has fastened to the fruit surface by silken threads.

Of the injury caused by the young larva solely that affecting the fruit seems to be of interest from an economic point of view. Amongst the commercial fruit growers the general type of fruit injury is well known. The larva breaks through the skin, causing a varying number of small and shallow holes or depressions (cf. fig. 9).

Normally, no doubt, the hibernation takes place on the tree. The larva of *Arg. variegana*, like that of *Pand. ribeana, Cac. podana, Spil. ocellana* and *Pand. heparana*, hibernates in a silken nest, placed e. g. in a crack at or near the end of a twig. Probably the same is true of the larva of *Cac. lecheana.*

The larva emerges from hibernation in the spring, about the time when the apple buds are beginning to open. It constructs a shelter, e. g. by binding together unopened flowers and leaves with silk, and resumes feeding.

Sometimes the old larva of *Cac. lecheana, Pand. ribeana* and *Cac. podana,* possibly also *Pand. heparana*, gnaws on the flower trusses. Chiefly, however, these four species seem to feed on the developing foliage. The old larva of *Arg. variegana*, like that of *Spil. ocellana,* frequently feeds on both the flower trusses and the leaves.

It does happen that the old larva of *Spil. ocellana* bores into the newly set


Fig. 10. Left. Young apple fruit injured by an old *Pandemis* larva. Nat. size. — Right. Pupal case of *Spilonota ocellana* protruding from a cocoon attached to an apple stem. Nat. size.

fruit, causing more or less conspicuous holes or excavations. The same is true of the old larva of *Pand. heparana;* according to observations in Great Britain (Hey and Thomas 1934) also of the old larva of *Cac. podana.*

The pupation takes place with few, if any exceptions on the tree. Often the pupa of *Spil. ocellana* is to be found in a cocoon on the bark. Frequently at least, the remaining species pupate amongst the leaves.

The pupal period generally lasts about two to three weeks. It tends to be somewhat longer in *Spil. ocellana* than in the other species. Figures showing the length of the period in some pupae kept in an outdoors insectary at Åkarp are presented in table 4.

2. *Species hibernating in the egg stage.* There are five species in this group: *Acr. naevana, Cac. rosana, Cac. xylosteana, Acl. holmiana* and *Acl. reticulana.* The chief points of the life-history are as follows:

Normally the eggs are laid singly (*Acr. naevana, Acl. holmiana, Acl. reticulana*) or in batches (*Cac. rosana, Cac. xylosteana*) on the bark (cf. p. 147). The eggs of *Acr. naevana,* like those of *Cac. rosana,* are frequently found on branches measuring several cm. in diameter. The two *Acleris* species seem to prefer ovipositing on thin branches, e.g. on the spurs.

The larva hatches from the egg in the spring and feeds on the developing foliage. The problem, whether it attacks the flower trusses or not, needs further investigation.[1] Sometimes the larva of *Acr. naevana, Cac. rosana, Acl.*

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[1] According to Baggiolini (1956) *Cac. rosana* frequently attacks and destroys the flowers.

Table 4. Records of the pupal instar, Åkarp 1956.

Note: The pupae were kept in inverted Petri dishes, several placed one on top of the other, in shady positions on a table in a shelter mounted out-of-doors. The photo reproduced in fig. 29 (p. 208) gives a view of the arrangements. The shelter to the right of the picture is that mentioned above.

The lid and the container of each Petri dish were separated from each other by muslin sewn on to an iron ring. The chamber below the cloth contained water, the chamber above the cloth the pupa(e).

The dishes were examined daily, generally towards the middle of the day. It is supposed in the table that pupation and emergence only occurred at 9 a. m.

The figures in the last column of the table indicate the temperature conditions about 25 m. away from the pupae, in a screen of the type shown in fig. 55. Each figure is calculated on the basis of the hourly temperatures recorded by the thermograph mentioned on p. 260.

Number of		Date of pupation	Date of adult emergence	Pupal period	
male pupae	female pupae			Length in days	Average temp. in °C
Argyroploce variegana					
—	1	June 2	June 22	20	15·1
—	1	„ 3	„ 22	19	15·1
2	1	„ 5	„ 23	18	15·1
1	1	„ 5	„ 24	19	15·1
—	1	„ 6	„ 24	18	15·1
—	1	„ 6	„ 25	19	15·2
—	1	„ 7	„ 26	19	15·1
1	—	„ 8	„ 26	18	15·0
1	2	„ 8	„ 28	20	14·8
—	1	„ 9	„ 29	20	14·6
Pandemis ribeana					
1	—	June 5	June 22	17	15·1
—	1	„ 10	„ 28	18	14·4
—	1	„ 12	July 1	19	13·8
—	1	„ 13	„ 3	20	14·1
1	1	„ 15	„ 4	19	14·4
1	—	„ 17	„ 8	21	14·7
—	1	„ 18	„ 5	17	14·8
1	—	„ 18	„ 8	20	14·8
1	—	„ 18	„ 9	21	14·8
—	1	„ 20	„ 11	21	15·1
1	—	„ 21	„ 11	20	15·1
-	1	„ 22	„ 11	19	15·2
Cacoecia podana					
—	1	June 16	July 4	18	14·5
1	—	„ 17	„ 7	20	14·7
1	—	„ 17	„ 8	21	14·7
—	1	„ 21	„ 9	18	14·9
1	—	„ 21	„ 12	21	15·3
—	1	„ 22	„ 10	18	15·1
—	1	„ 22	„ 11	19	15·2
1	—	„ 24	„ 12	18	15·4
—	1	„ 26	„ 12	16	15·4
—	1	„ 26	„ 13	17	15·5
1	—	„ 28	„ 16	18	16·1
—	1	„ 29	„ 14	15	16·2
1	—	July 3	„ 20	17	16·8
1	—	„ 4	„ 21	17	16·6

Table 4. Continued.

Number of		Date of pupation	Date of adult emergence	Pupal period	
male pupae	female pupae			Length in days	Average temp. in °C
Cacoecia rosana					
1	—	June 20	July 12	22	15·2
—	1	„ 23	„ 10	17	15·0
1	—	„ 23	„ 12	19	15·4
1	—	„ 24	„ 12	18	15·4
1	—	„ 27	„ 15	18	15·9
—	1	July 4	„ 19	15	16·6
—	1	„ 5	„ 19	14	16·6
—	1	„ 5	„ 20	15	16·6
—	1	„ 9	„ 23	14	17·8
—	1	„ 11	„ 27	16	17·4
Spilonota ocellana[1]					
1	—	June 15	July 11	26	14·8
—	1	„ 15	„ 12	27	14·9
1	—	„ 16	„ 11	25	14·9
1	—	„ 16	„ 12	26	15·0
—	1	„ 19	„ 13	24	15·3
—	1	„ 19	„ 14	25	15·4
1	3	July 1	„ 21	20	16·8
1	2	„ 1	„ 22	21	16·9
1	2	„ 2	„ 22	20	16·9
—	1	„ 2	„ 25	23	17·0
1	2	„ 3	„ 22	19	16·8
—	2	„ 3	„ 23	20	16·8
1	—	„ 4	„ 23	19	16·7
—	2	„ 4	„ 24	20	16·8
1	2	„ 4	„ 25	21	16·8
—	2	„ 5	„ 25	20	16·9
1	—	„ 5	„ 27	22	17·0
—	1	„ 6	„ 26	20	17·0
2	—	„ 11	„ 30	19	17·8
Pandemis heparana					
—	1	June 23	July 10	17	15·0
1	—	„ 25	„ 13	18	15·5
1	—	July 4	„ 20	16	16·6
1	—	„ 5	„ 22	17	16·7
—	2	„ 11	„ 24	13	17·3
1	—	„ 14	„ 30	16	17·8
1	—	„ 15	„ 29	14	17·2
—	1	„ 19	Aug. 4	16	16·6
Acleris reticulana					
1	—	June 21	Aug. 11	51	15·9
1	—	„ 23	„ 9	47	16·0
—	1	„ 23	„ 29	67	15·5
1	—	„ 24	„ 17	54	15·8
—	1	„ 26	„ 14	49	15·9
—	1	„ 26	„ 17	52	15·9
1	—	„ 27	„ 14	48	16·0
—	1	„ 27	„ 22	56	15·8
—	1	„ 29	„ 11	43	16·2

[1] Figures are also available for some additional individuals of *Spil. ocellana.* They all pupated in the dishes in the period June 20—30. The pupal period for these individuals varied between 20 and 25 days.

Fig. 11. Apple twigs infested by larvae of *Acroclita naevana* (A), *Cacoecia rosana* (B) and *Acleris reticulana* (C). Nat. size.

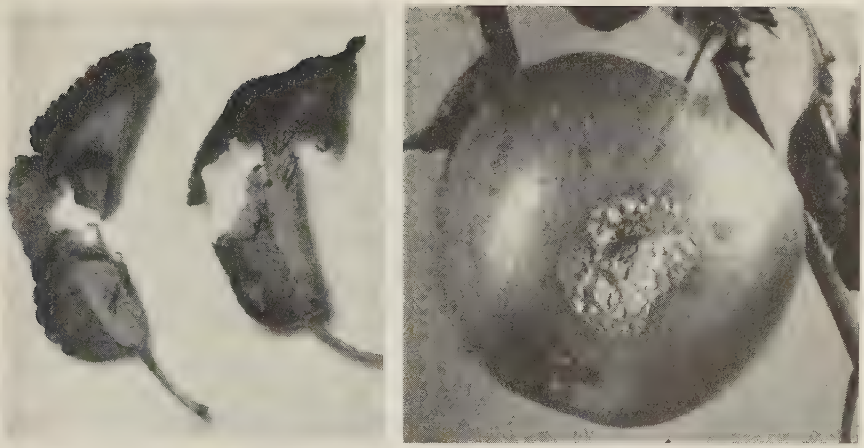


Fig. 12. Left. Apple leaves injured by almost full-grown larvae of *Acleris holmiana*. Nat. size. — Right. Apple fruit showing scar caused by the feeding of a nearly full-grown *Cacoecia* larva. Nat. size.

holmiana and *Acl. reticulana*, perhaps also that of *Cac. xylosteana*, feeds on the young fruits.

Cac. rosana, Cac. xylosteana and *Acl. holmiana* pupate, as a rule at least, on the tree amongst the leaves. *Acr. naevana* sometimes pupates on the tree, sometimes in the soil. *Acl. reticulana* always, or practically always, pupates in the soil.

The pupal period generally lasts about two to three weeks, in *Acl. reticulana* about six to eight weeks. Some figures of the pupal instar (*Cac. rosana, Acl. reticulana*) are to be found in table 4.

Chemical control

The data in this chapter bear upon the control of the pests under field conditions on apple, unless otherwise stated.

By buds, the compound apple buds are meant, i.e. the buds, each of which gives rise to both leaves and flowers.

Concerning the development stages of the buds, the standardised system in use in Great Britain is followed. The stages may be briefly described thus:

Dormant.	Buds dormant. Entirely enclosed in bud scales.
Swelling.	Buds swelling. Not yet showing green.
Breaking.	Buds green but only at the tips.
Burst.	Buds opening but leaves not yet unfolding.
Mouse ear.	Outer leaves unfolding. Inner leaves beginning to separate but still covering parts of flower truss.

Green cluster.	Leaves widely separated, no longer covering flower truss. Latter green, in tight cluster.
Pink.	Flowers showing pink but still unopened.

Illustrations in colour of the various stages are to be found in a leaflet edited by the British "Ministry of Agriculture and Fisheries" (Anon. 1949).

Both control experiments carried out by other workers and experiments made in connection with the studies at Åkarp are discussed in the following pages. Regarding some of the former and also some of the latter experiments the larvae were not identified to species. Theoretically it is possible that in some cases all the species reared at Åkarp and even other fruit leaf tortricids occurred.

To avoid misunderstandings it should be pointed out that *fruit leaf tortricid infestation* always means the infestation as indicated by the total number of individual fruit leaf tortricid larvae present.

The sprays used in the experiments discussed in tables 5—10 were (except nicotine spray) made from commercial preparations. The quantity of active ingredient in the different preparations is considered to be that recorded by resp. manufacturers or their chief agents. By parathion, ethyl-parathion is meant.

Winter washes

Dormant spraying with tar distillate has been tested several times. Hartzell (1942), for example, used coal tar oil against the hibernating larvae of *Spil. ocellana*. Judging from his figures a thorough application (3—4½ lit. per 100 lit. spray) often results in 65—75 per cent of the larvae being killed. Gonggrijp (1946) has presented the results of a series of tests, in which fruit trees received a 6 per cent fruit tree carbolineum spray. The figures indicate that the spray caused a reduction of the fruit leaf tortricid infestation varying between about 30 and a good 80 per cent.

DNC (dinitro-o-cresol) shows promising results. Hartzell (1943), in trials for the control of *Spil. ocellana*, used about 0.14 kg. DNC (no oil) per 100 lit. spray in one test, about 0.10 kg. DNC (plus 1, 2 or 3 lit. oil) per 100 lit. in five other tests. His figures indicate that the various sprays caused more than a 95 per cent reduction of the pest. Dicker and Briggs (1952), in studies on the control of fruit leaf tortricids, used about 0.07 kg. DNC (plus oil) per 100 lit. spray in one year, about 0.10 kg. DNC (plus oil) per 100 lit. in another year. The sprays resulted in a considerable reduction of the fruit leaf tortricid infestation. Probably about 85—95 per cent of the larvae were killed, in both years.

There seem to be no data, however, indicating tar distillate or DNC to be useful for the control of fruit leaf tortricids hibernating in the egg stage. Recently Baggiolini (1956) tested the susceptibility of the eggs of *Cac. ro-*

sana to various winter washes. A mineral oil killed about 85—90 per cent of the eggs, but the remaining materials tested, e. g. tar distillate and DNC, failed to give a satisfactory control.

Generally, the commercial orchards in Scania are no longer sprayed during winter, nor during spring before the breaking of the buds. It is a common opinion among the growers that the spring-summer washes in use give a sufficiently good pest control and that they are safer for the trees than both fruit tree carbolineum and DNC plus petroleum. Winter washes were not tested in connection with the investigations at Åkarp.

Spring-summer washes

Pre-blossom sprays

In experiments for the control of *Spil. ocellana* Conklin and Walker (1949) obtained good results with parathion (about 0.035 kg. per 100 lit. spray). Judging from their figures the effect was 80—90 per cent or still higher, both in the case of a spray applied on April 7 and in the case of a spray applied somewhat later, on April 12. A parathion-sulphur spray applied at the green cluster stage, on May 4, resulted in a high degree of control, counts made on May 10 indicating an effect of more than 90 per cent.

Dicker and Briggs (1952) compared the efficiency of DDT and parathion sprays. The tests were conducted in 1949—1950, the sprays being applied on April 19 (green cluster stage almost passed) in the former year, on April 4 (buds varying from mouse ear to green cluster) in the latter year. Examinations of buds indicated that DDT (0.05 kg. per 100 lit. spray) in 1949 caused more than a 90 per cent reduction of the fruit leaf tortricid infestation but in 1950 only about 60—70 per cent; parathion (0.01 kg. per 100 lit. spray) in 1949 less than a 50 per cent reduction but the same insecticide (0.005 kg. per 100 lit. spray) in 1950 more than 85 per cent.

Baggiolini (1956) points out that the most suitable time for spraying against *Cac. rosana* (in western Switzerland) is at the pink stage of the buds. In tests in which the sprays were applied at early pink bud in 1955 diazinon and parathion showed the most promising results, the counts indicating an effect of more than 90 per cent for both materials. Each of the two insecticides was used at the rate of 0.02 kg. per 100 lit. spray.

In connection with the investigations at Åkarp lindane, malathon and parathion were tested in a 9 year old apple plantation in the spring of 1955. A block of 138 trees (two rows, one containing 69 Cox' Orange, the other 69 Ingrid Marie trees) was divided into three plot series (series A, B and C). Each series included four 10-tree plots and one 6-tree plot. Sprays were applied twice: on May 9 (buds varying between burst and mouse ear) and

Table 5. Results of a field experiment for the control of fruit leaf tortricids; Billeberga, spring 1955.

Treatment[1] etc.	Spray date(s)	Tree plot in series	Number of live larvae recorded				Total no. of larvae recorded
			Spil. ocellana		Other species		
			On Cox' Orange	On Ingrid Marie	On Cox' Orange	On Ingrid Marie	
Check no treatment		A	4	0	34	22	
		B	4	0	37	23	
		C	0	1	57	54	
		Sum	8	1	128	99	236
Lindane 0.02 kg. per 100 lit.	May 9	A	2	1	11	12	
	„ 23	B	0	1	13	13	
		C	0	0	18	14	
		Sum	2	2	42	39	85
Parathion 0.018 kg. per 100 lit.	May 23	A	1	0	1	5	
		B	0	1	6	4	
		C	1	0	14	8	
		Sum	2	1	21	17	41
Malathon 0.15 kg. per 100 lit.	May 9	A	0	0	0	1	
	„ 23	B	0	0	0	1	
		C	0	0	4	2	
		Sum	0	0	4	4	8
Parathion 0.018 kg. per 100 lit.	May 9	A	0	0	0	0	
	„ 23	B	0	0	0	0	
		C	0	0	1	1	
		Sum	0	0	1	1	2

[1] Lindane sprays prepared from a wettable powder, remaining sprays from emulsion concentrates.

on May 23 (at green cluster). Some plots, however, were only treated on May 23 (with parathion) and the 6-tree plots were left untreated as checks.

A motorsprayer equipped with a portable pipe was used and the sprays were applied at a pressure of about 25—30 kg. per sq. cm. At each application the consumption of spray averaged about 2½—3 lit. per tree. The average height and width of the trees were about 2—3 and 3—4 m. respectively.

Later, all the trees in the check plots and the six middlemost trees in each of the remaining plots were examined, each tree thoroughly from all quarters. The examination dates were May 26 (series A), May 27 (series B) and June 2 (series C). A total of several hundreds of injured or webbed-together buds or leaves were detected, all of which were inspected with regard to the occurrence of tortricid larvae. Table 5 shows the number of live larvae recorded in the various plots.

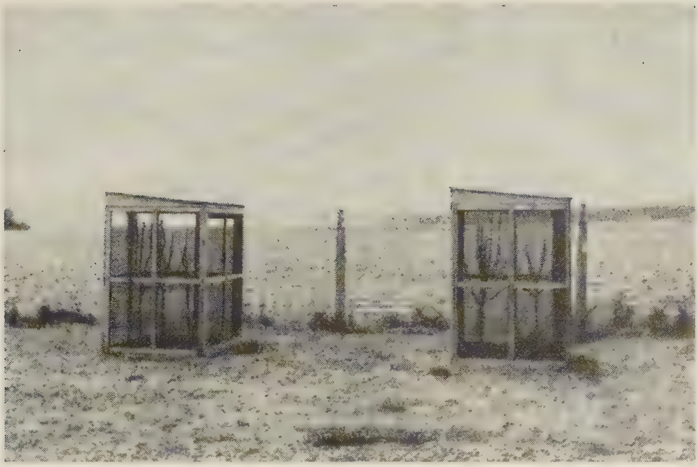


Fig. 13. Two of the cages used in the control experiments against adult moths.

From the examinations it can be concluded that the combined effect of the early and the late application was sufficiently high, in the case of both malathon and parathion. Lindane gave less good control.

It is worth mentioning that the weather was fairly cold in Scania during most of May in 1955. The air temperature in the above-mentioned orchard (1½ m. above the ground) was about 15 °C during the application period on May 9, about 6½-10° during the corresponding period on May 23. According to the records of the Swedish Meteorological and Hydrological Institute the daily maximum at Malmö (located about 31 km. south of the orchard) varied between 9.3 ° and 13.2 ° during the period from May 10 to and including May 27.

Post-blossom sprays

The spray experiments of Harman (1932) indicate that *Spil. ocellana* can be effectively controlled by summer applications of lead arsenate. In one of his experiments two applications (June 29, July 13), three applications (June 29, July 13, July 27) and four applications (June 29, July 13, July 27, Aug. 13) resulted in only about 15, 6 and 3 per cent of the fruits being injured by the new generation larvae, against about 34 per cent for no treatment. At each application the lead arsenate was used at the rate of about 0.36 kg. per 100 lit. spray.

De Jong (1951), in his studies on *Adoxophyes orana* (cf. p. 139), found in laboratory tests that both the adult moths and the young larvae (the 2—3 first instars) were very sensitive to various insecticides, e.g. DDT and parathion. Also summer applications in the field showed a reducing effect

Table 6. Control experiments against adult moths (kept confined in
A = number of moths at beginning of experiment. B =

Experiment no.	Treatment[1] etc.	Trees sprayed on	Experiment begun on	*Cacoecia rosana* ♂ A	♂ B	♀ A	♀ B	Total A	Total B
II	Check	—	July 10	4	4	1	0	12	9
V	„	—	„ 20	2	2	5	3		
II	DDT	July 10	„ 10	3	2	1	0	11	7
V	„	„ 20	„ 20	2	2	5	3		
III	Check	—	„ 12	4	4	4	4	12	11
VI	„	—	„ 24	—	—	1	1		
VII	„	—	„ 28	2	2	1	0		
III	Lindane	July 12	„ 12	4	3	4	3	12	8
VI	„	„ 12, 24	„ 24	—	—	1	1		
VII	„	„ 12, 24, 28	„ 28	2	1	1	0		
III	Check	—	„ 12	4	4	4	4	9	9
VI	„	—	„ 24	—	—	1	1		
VIII	„	—	Aug. 4	—	—	—	—		
III	Malathon	July 12	July 12	4	0	4	1	9	1
VI	„	„ 12, 24	„ 24	—	—	1	0		
VIII	„	„ 23, Aug. 4	Aug. 4	—	—	—	—		
I	Check	—	July 9	3	2	1	1	8	5
IV	„	—	„ 16	1	0	—	—		
IX	„	—	Aug. 7	1	0	2	2		
I	Parathion	July 9	July 9	3	0	1	0	8	0
IV	„	„ 16	„ 16	1	0	—	—		
IX	„	„ 16, Aug. 7	Aug. 7	1	0	2	0		

[1] All sprays were prepared from emulsion concentrates. Quantity of active ingredient 0.017 kg. (parathion).

upon the pest. In one experiment a spray of DDT (0.1 kg. per 100 lit.) and a spray of parathion (0.015 kg. per 100 lit.), both applied on Aug. 7, caused only about 0.6 and 4.5 per cent of the fruits being injured by the second generation larvae. For no treatment the figure was about 15.4 per cent.

Groves and Tew (1953), in a summer experiment for the control of the same species, used 0.01 kg. parathion or 0.15 kg. toxaphene or 0.1 kg. DDT plus 0.01 kg. parathion per 100 lit. spray. Some trees were sprayed only once (June 5), others twice (June 5, June 23). Whilst the percentage of fruits damaged by the first generation larvae amounted to about 20 for

cages containing untreated or sprayed apple trees), Åkarp 1954. number of live moths recorded at end of experiment.

Experiment no.	*Spilonota ocellana* ♂ A	♂ B	♀ A	♀ B	Total A	Total B	Both species Total A	Total B	B in relative figures (check = 100)
II	2	2	1	1	8	8	20	17	
V	4	4	1	1					
II	2	0	2	2	9	6	20	13	76
V	4	4	1	0					
III	1	1	—	—	17	15	29	26	
VI	1	1	3	3					
VII	10	8	2	2					
III	1	1	—	—	17	10	29	18	69
VI	1	0	3	2					
VII	10	5	2	2					
III	1	1	—	—	14	14	23	23	
VI	1	1	3	3					
VIII	2	2	7	7					
III	1	0	—	—	14	2	23	3	13
VI	1	0	3	0					
VIII	2	0	7	2					
I	4	2	1	1	19	16	27	21	
IV	—	—	6	6					
IX	3	3	5	4					
I	4	0	1	0	19	2	27	2	10
IV	—	—	6	1					
IX	3	0	5	1					

(per 100 lit. spray) was 0.05 kg. (DDT), 0.015 kg. (lindane), 0.1 kg. (malathon), and

no treatment, the figure for one application of parathion was about 17, one and two applications of toxaphene 12 and 10, one application of DDT plus parathion 9 and two applications of parathion 7.

In an experiment series at Åkarp in 1954 the susceptibility of the adult moths of *Cac. rosana* and *Spil. ocellana* to DDT, lindane, malathon and parathion was tested. Apple trees, less than 5 years old and growing in pots, were thoroughly sprayed ("rich wetting"). A pneumatic knapsack sprayer was used and the sprays were applied at a pressure of about 8 kg. per sq. cm. As soon as they were dry, the trees were put into nylon mesh cages (cf.

fig. 13), whereupon the moths were introduced. The cages, each of which was about 1 m. long by 1 m. wide and 1½ m. high, were mounted in an open place outdoors. In each experiment three untreated trees were kept in one cage, three trees sprayed with one of the four insecticides in another cage etc. Several times the different trees included in one experiment were later used in another experiment. Thus, some of the trees were sprayed more than once. Complete figures of the spray dates are given in table 6.

Reared moths were used and they were distributed among the cages as evenly as possible, also as regards their age after their emergence from the pupa. At the end of the different experiments (three or four days after the trees and the moths had been brought together) the cages were thoroughly inspected. All moths discovered were collected and counted.

Table 6 shows the results. DDT and lindane only gave a small, if any control. Malathon, and also parathion, reduced the number of moths considerably.

In some other spray experiments at Åkarp in 1954 apple stocks infested by young larvae were used. At the beginning of the experiment period the age of the larvae was less than 8 days, in most of the experiments less than 5 days. With regard to each experiment each larva occurred, when the spray was applied (or at least shortly before it), in a silken nest on the leaf surface.

For the various experiments only untreated stocks were selected. Each experiment included two or more stocks, all but one of which were sprayed ("rich wetting"), the knapsack sprayer mentioned above being used. Pre- and post-treatment counts of the larvae were made, the latter on the second day after application. During the interval between the application and the post-treatment count the stocks were kept either outdoors (experiments begun on June 29 and July 6) or in an unheated glasshouse (remaining experiments).

The results are summarized in table 7. All the insecticides tested caused a reduction of the infestation, but only malathon and parathion showed a consistently high effect.

Summer treatments of malathon, against new generation larvae of the species hibernating in the larval stage, were tested in 1955 in a 9 year old apple plantation. Two tree rows were used, one containing 40 Laxton's Superb trees and the other 40 Bodil Neergaard trees. Each row was divided into four 10-tree plots.

Details of the insecticidal treatment are given in table 8. It will be seen that four plots received two applications of malathon (July 14, July 27). At the first application the spray included no fungicide, but at the second captan (0.2 kg. per 100 lit. spray) was added to the insecticide. On both occasions the motorsprayer discussed on p. 170 was used, the spray being

Table 7. Control experiments against young larvae on apple stocks, Åkarp 1954.
A = number of larvae at beginning of experiment. B = number of larvae on the stocks at end of experiment.

	Spray date	Check			DDT			Diazinon			Nicotine			Lindane			Malathon			Parathion		
		A	B Live	B Dead	A	B Live	B Dead	A	B Live	B Dead	A	B Live	B Dead	A	B Live	B Dead	A	B Live	B Dead	A	B Live	B Dead
Cac. lecheana	June 29	7	5	0	—	—	—	33	21	12	—	—	—	—	—	—	—	—	—	10	1	6
Arg. variegana	July 6	10	10	0	—	—	—	—	—	—	—	—	—	—	—	—	18	0	18	—	—	—
Pand. ribeana	„ 13	7	7	0	—	—	—	8	0	6	—	—	—	—	—	—	15	2	10	16	0	15
„ „	„ 17	5	5	0	6	3	1	—	—	—	—	—	—	9	1	6	20	0	15	13	0	10
„ „	„ 20	8	8	0	—	—	—	—	—	—	10	6	4	—	—		—	—	—	—	—	—
Cac. podana	„ 17	3	3	0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	5	0	4
„ „	„ 20	8	8	0	11	1	2	10	3	5	9	0	5	—	—	—	—	—	—	—	—	—
„ „	Aug. 7	6	6	0	—	—	—	—	—	—	9	0	5	7	1	6	—	—	—	—	—	—
Spil. ocellana	July 26	9	9	0	16	10	4	13	5	7	11	6	4	14	5	8	—	—	—	—	—	—
„ „	Aug. 19	10	10	0	—	—	—	—	—	—	—	—	—	—	—	—	15	1	13	11	0	10
Pand. heparana	July 26	10	9	0	—	—	—	—	—	—	—	—	—	15	6	7	—	—	—	—	—	—
	Sum	83	80	0	33	14	7	64	29	30	39	12	18	45	13	27	68	3	56	55	1	45
Percentage dead of larvae refound				0			33			51			60			68			95			98

Note: All sprays (except nicotine) were prepared from emulsion concentrates. Quantity of active ingredient (per 100 lit. spray) was 0.05 kg. (DDT), 0.03 kg. (diazinon), 0.2 kg. (nicotine), 0.015 kg. (lindane), 0.1 kg. (malathon), and 0.017 kg. (parathion).

Table 8. Results of a field experiment for the control of fruit leaf tortricids hibernating in the larval stage; Billeberga, summer 1955.

Insecticidal treatment[1] etc.	Spray dates	Extent of fruit injury caused by new generation larvae				
		Series A Laxton's Superb		Series B Bodil Neergaard		
		Number apples counted	Number apples injured	Number apples counted	Number apples injured	Percentage apples injured Average per tree
Check I No insecticide	—	300	6	600	79	13·2±0·7
Check II No insecticide	—	200	3	600	77	12·8±2·3
Malathon 0.075 kg. per 100 lit.[2]	July 14 „ 27	200	0	600	34	5·7±0·8
Malathon 0.15 kg. per 100 lit.[3]	July 14 „ 27	300	1	600	10	1·7±0·4

[1] Applies to the period after the end of June. Earlier in the year all the trees received four insecticidal applications, viz. two before blossom — May 11 (lindane) and May 24 (lindane plus parathion) — and two after blossom — June 23 (parathion) and June 29 (parathion).
[2] Prepared from a wettable powder.
[3] Prepared from an emulsion concentrate.

applied at a pressure of about 25—30 kg. per sq. cm. The consumption of spray per tree and application averaged about 4—4½ lit. The average height and width of the trees were about 2—3 and 3—4 m. respectively.

Counts of the fruit injury were made on Aug. 18. In the case of Laxton's Superb the examinations included all trees bearing 100 apples or more, in the case of Bodil Neergaard the six middlemost trees in each of the four 10-tree plots. On each tree a hundred apples were examined.

The results are summarized in table 8. On Laxton's Superb the fruit injury was very slight, even in the check plots. On Bodil Neergaard it was fairly severe in the check plots but slight in the plots sprayed with malathon. Particularly the counts made on Bodil Neergaard indicate that the malathon sprays reduced the fruit leaf tortricid infestation considerably.

It is worth noting that the foliage was much thinner on Laxton's Superb than on Bodil Neergaard. Generally, the fruits on Laxton's Superb occurred solitarily on the fruit spurs, and only few of them were in contact with leaves. Frequently, on the other hand, the fruits on Bodil Neergaard occurred in twos or in clusters, and many of them were in contact with leaves. Since the fruit leaf tortricid larva prefers feeding in a concealed location,

Table 9. Results of a field experiment for the control of fruit leaf tortricids hibernating in the larval stage; Billeberga, summer 1956.

Insecticidal treatment[1] etc.	Extent of fruit injury caused by new generation larvae					
	Series A Bramley		Series B Bramley		Series C Bramley	
	Number apples counted	Percentage apples injured	Number apples counted	Percentage apples injured	Number apples counted	Percentage apples injured
Check No insecticide	500	8·4	500	3·2	500	5·0
Malathon, Aug. 6 0.075 kg. per 100 lit.[2]	472	3·0	500	1·8	500	2·4
Malathon, Aug. 6 0.15 kg. per 100 lit.[2]	500	3·4	500	2·2	433	2·8
Parathion, Aug. 6 0.014 kg. per 100 lit.[2]	400	0·8	484	2·9	500	1·6

[1] Applies to the period after the end of July. Once in July and several times earlier in the year all the trees received insecticidal material. The July spray (applied by the grower on July 21) contained parathion.
[2] Prepared from an emulsion concentrate.

e. g. between a leaf and a fruit (cf. p. 159 ff.), it is only natural that Laxton's Superb showed a less degree of fruit injury than Bodil Neergaard.

Another control experiment was conducted in the same orchard in the summer of 1956. A tree row containing 60 Bramley trees was used. It was divided into 5-tree plots. Data of the insecticidal treatment are to be found in table 9. The trees received, during July—August, one or two applications (all tree plots parathion on July 21, nine plots either parathion or malathon on Aug. 6).

The figures of fruit injury (caused by the new generation larvae of the species hibernating in the larval stage) given in table 9 refer to counts made on Sept. 14. There was a tendency to less damage in the tree plots sprayed both in July and in August than in the plots sprayed in July but not in August. In all the plots, however, the injury was slight or fairly slight and the differences are not significant.

Also in the summer of 1957 an experiment was carried out. In an 11 year old orchard a tree row containing 60 Belle de Boskoop trees was divided into three plot series. Each series included four 5-tree plots. During the experiment period all the trees were sprayed twice (July 31, Aug. 13). On both occasions the trees in the check plots received only a fungicide (ziram; 0.14 kg. per 100 lit. spray), the remaining trees a fungicide (ziram; dosage as above) combined with insecticide material. Data of the insecticidal treat-

Table 10. Results of a field experiment for the control of fruit leaf tortricids hibernating in the larval stage; Billeberga, summer 1957.

Insecticidal treatment[1] etc.	Extent of fruit injury caused by new generation larvae						
	Series A Belle de Boskoop		Series B Belle de Boskoop		Series C Belle de Boskoop		Series A—C
	Number apples counted	Number apples injured	Number apples counted	Number apples injured	Number apples counted	Number apples injured	Percentage apples injured Average per tree
Check No insecticide	421	71	500	85	500	86	17·1±1·3
Dimethyl-phosphonate 0.06 kg. per 100 lit.[2] .	500	22	500	23	400	19	4·6±0·5
Parathion 0.014 per 100 lit.[2]	500	15	500	20	500	8	2·9±0·6
Malathon 0.1 kg. per 100 lit.[2] .	428	14	475	13	500	9	2·4±0·6

[1] Applies to the period after the middle of July. Earlier in the year all the trees received four insecticidal applications (lindane).
[2] Prepared from an emulsion concentrate.

ment are included in table 10. One of the insecticides used, dimethyl-trichlorohydroxyethyl-phosphonate, is called dimethyl-phosphonate both in the table and in the following text.

The sprays were applied according to the methods discussed on p. 170. At each application the consumption of spray was about 4—4½ lit. per tree. The height and the width of the trees averaged about 2—3 and 3—4 m. respectively.

Counts of the fruit injury (caused by the new generation larvae of the species hibernating in the larval stage) were made on Sept. 18. On trees bearing less than 100 apples all the fruits were examined, on each of the remaining trees 100 fruits.

The results of the counts are given in table 10. As can be seen, all the insecticides tested (dimethyl-phosphonate, parathion, malathon) gave a high degree of control.

No doubt fruit leaf tortricids can often be effectively controlled during spring, e.g. by applying parathion or malathon at the times when the buds are in the burst stage, the mouse ear stage or in the green cluster stage. Regarding the different species hibernating in the larval stage, however, the reinfestation in summer exercises a trouble, e.g. in orchards adjoining neglected and severely infested gardens.

For control work in summer several insecticides are useful, e.g. parathion, malathon and dimethyl-phosphonate. The problem of when to spray during summer is discussed on p. 287 ff.

Note: Recently Hammarlund (1958) published the results of a field experiment (in Denmark in 1957) for the control of fruit leaf tortricids on apple. In the case of each of the insecticides tested the spray dates were April 2, April 17, June 13, July 9 and Aug. 22. According to counts made towards the end of May (number of injured shoots) and in September—October (number of injured fruits) the effect of some of the materials was as follows:

	Spring on shoots	Autumn on fruits
Gusathion	77 %	98 %
Malathon	76	86
Parathion	89	84
DDT	71	83
Dimethyl-phosphonate	86	72
Lindane	78	37

Studies on periodicity of the adult moths

Experiments with caged moths

Annual period of flight

Extensive rearing experiments were carried out at Åkarp in 1952—1953. These experiments and some studies made in connection with them are dealt with in this chapter.

Three wire cages — cage *a*, *b*, and *c* — were used (cage *c* not, however, until in 1953). The cages were kept outdoors: cage *a* (in both years) in the place marked *a* on the map, fig. 38 (p. 221), cage *b* (in both years) in the place marked *b*, and cage *c* (in 1953; cf. above) in the place marked *c*. The photograph reproduced on p. 181 was taken during the experiments in 1953. It shows the cages from the north.

Cages *a* and *b* were of the same size and appearance. Each of them occupied a plot of about 2 × 1⅓ m. The roof chiefly consisted of window-glass and was first kept limed but later (from June 9, 1952) covered with a mat of reeds.

Cage *c* occupied a plot of about 2×2 m. The roof consisted of one exterior and one interior part, the former being partially made up of window-glass, the latter being of wire net. The window-glass was not kept limed, nor covered.

Several small apple trees were grown in the cages. Cages *a* and *b* contained 5 or more trees each, cage *c* about 10 trees.

Table 11. Number of larvae (including pupae) of fruit leaf tortricids (including Recurvaria) placed in the cages, Åkarp 1952—1953.

Year	Period when larvae incl. pupae were collected[1] and put into the cages	Number of specimens put into					
		cage *a*		cage *b*		cage *c*	
		Larvae[2]	Pupae	Larvae[2]	Pupae	Larvae[2]	Pupae
1952	May 13—June 6	1,100	8	1,100	8	—	—
1953	April 29—May 11	0	0	0	0	800	0
	May 15—June 1	1,000	3	1,000	7	0	0
	June 2—June 9	0	0	0	0	400	3

[1] As mentioned in text, only larvae-pupae gathered on apple trees at or near Åkarp were handled. All specimens recorded on the trees inspected were collected and all of them (except some of the larvae obtained during period June 2—9, 1953) were put into the cages.

[2] Figures rounded to nearest hundred.

Fig. 14. View of the rearing cages, Åkarp 1953. In the foreground cage *a*, in the middle cage *b*, in the background cage *c*.

Table 11 gives a summary of the larval-pupal material. Solely specimens of fruit leaf tortricids (including the tineid *Recurvaria leucatella* Cl.) gathered at random on apple trees at or near (< 10 km. from) Åkarp were put into the cages. In 1952 a total of more than 2,000 specimens was placed on the trees in the cages, in 1953 a total of more than 3,000 specimens.

In collaboration with Mr Jan Mattsson some temperature registrations with thermistors (T-20-25, Institutet för Halvledarforskning, Stockholm) were carried out at Åkarp in August 1955. The measuring voltage was inconstant but a record of the variations was kept with the aid of a constant resistance connected with the same recorder (VRY 14, Ermi, Stockholm) as the thermistors. The different thermistors were calibrated twice (Aug. 6 and 17). All thermistor records were corrected for voltage variations. The accuracy of the calculated temperature figures lies between ± ½ °C.

In fig. 15, which is based on some of the above registrations, temperature data from two sunny days (Aug. 16 and 17) are given. One of the two curves shows the temperature 1 m. above the ground in cage *b* (which had the same site and was covered by a mat of the same kind as in 1952—1953). The remaining curve shows the temperature 1 m. above the ground in the open air about 30 m. from cage *b*, in the central part of the Substation orchard. As can be seen, the two curves differ very little from each other.

The cages were examined daily, in 1952 from June 3 to and including Sept. 9 (not, however, on Aug. 4, and Aug. 31), in 1953 from May 30 to and including Sept. 29 (not, however, on May 31).

According to the methods employed, the experiments can be divided into two groups. One of these groups, *the emergence experiments,* covers the

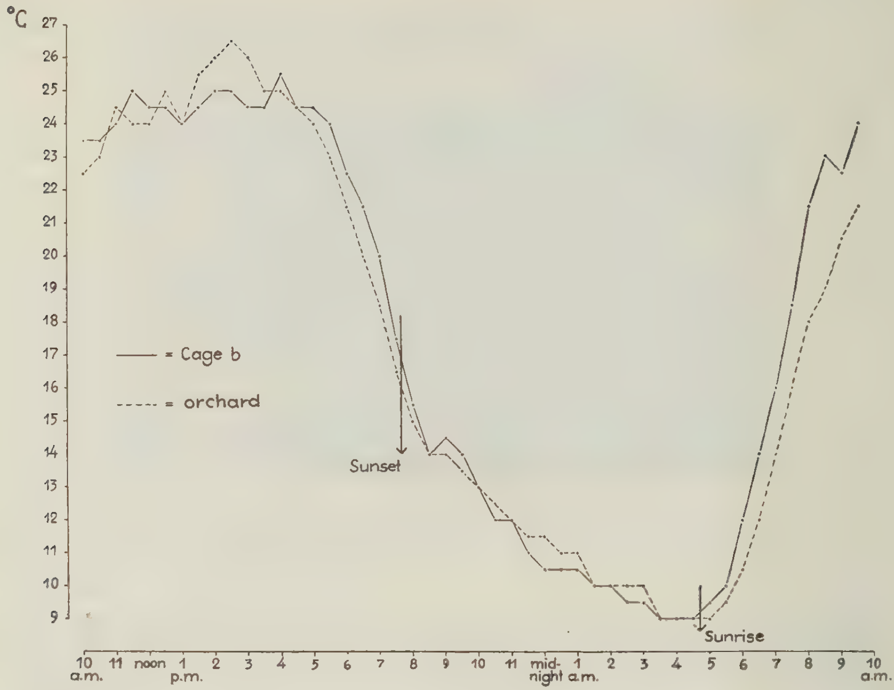


Fig. 15. Temperature (thermistor records) in cage *b* and in Substation orchard, Åkarp, Aug. 16—17, 1955.

Note: Each of the two thermistors was kept shielded against the sun by a piece of white cardboard. For further explanation see text, p. 181.

experiments in cage *a*, 1952—1953, and in cage *c*, 1953. All the adults recorded in these experiments were immediately collected and removed from the cages. The other group of experiments, *the population experiments,* covers the experiments in cage *b*, 1952—1953. The adults were not put to death or removed in these experiments, but were kept confined in the cage. The successive changes in the abundance of adults were studied.

With reference to the population experiments there are some exceptions from the above. In connection with the examinations in the cage some adults (according to the data available in all 13 specimens [5 of *Cac. rosana,* 2 of *Spil. ocellana,* 6 of other species]) succeeded in escaping from the cage or were unintentionally trampled to death, or else were lost for other reasons. The error caused by these accidents is disregarded in the continued discussion.

Each adult of *Cac. rosana, Spil. ocellana, Pand. heparana* and *Acl. reticulana* recorded in 1953 in the population experiments (cage *b*) was marked with cellulose paint on the upper side of one or both forewings. The paint

Table 12. Length of life of some marked and some unmarked male adults of Cacoecia rosana, Åkarp 1955.[1]

Emergence date	Marked moths		Unmarked moths	
	Moth no.	Length of life (days)	Moth. no.	Length of life (days)
July 15	1	13	1	11
„ 15	2	14	2	12
„ 16	3	8	3	12
„ 16	4	18	4	13
„ 16	5	4	5	12
„ 16	6	6	6	13
„ 17	7	13	7	11
„ 17	8	13	8	13
„ 18	9	10	9	8
„ 18	10	15	10	8
„ 19	11	8	11	11
„ 19	12	16	12	11
	Average	11·5		11·3

1 The moths were examined only once a day. As in text it is supposed that all moths emerged and died at the beginning of the day.

dried within some seconds after application and the spots were waterproof and permanent. Generally, the diameter of the spots was about 1—2 mm.

In experiments discussed by Dowdeswell, Fisher, and Ford (1940) adults of a butterfly, *Polyommatus icarus,* were marked with cellulose paint; during the operation each adult was held with a pair of forceps. Regarding tortricids, however, the use of a pair of forceps is not to be recommended. At Åkarp each moth was placed in a nylon net bag. The paint was applied by means of a pointed wooden stick through the holes in the nylon material.

A blue spot on the right forewing was considered to indicate the figure 1, a red spot the figure 2, etc.; a blue spot on the left wing the figure 10, a red spot the figure 20, etc. To facilitate the separation of sexes the females were marked with one spot more than the males.

In cage *b* in 1953 one or several not previously observed males of *Cac. rosana* were recorded on each of 18 days. The males observed on the first of these days were marked with "the figure 1", the males not observed until on the second day with "the figure 2", and so on. The same system was applied to the remaining moth series included in the marking operations.

Generally at least, the marking procedure or the presence of the spots seems to have had little or no effect at all on the length of life of the moths.

An experiment in which 24 males of *Cac. rosana* were used is of interest in this connection. The moths were kept, some of them from the day of emergence, the remainder from the day after emergence, in glass jars about 11 cm. high by 7 cm. wide. The jars were placed beside each other in a cage mounted in a

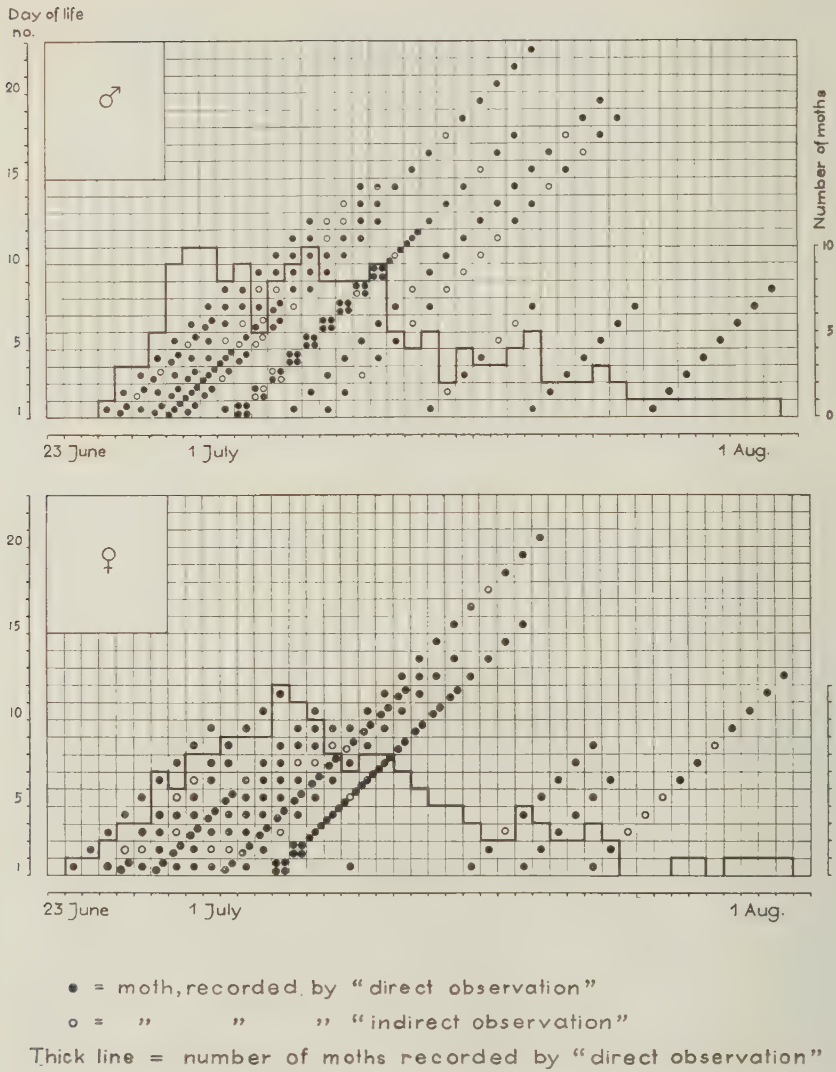


Fig. 16. Adult population of *Spilonota ocellana* in cage *b*, Åkarp 1953. Meaning of the term "direct observation" etc., see text, p. 185.

shady place outdoors. Each jar rested with the mouth down on a device consisting of a dish covered by muslin and containing water. In each jar either two moths which had been marked with cellulose paint (one spot [about 1—2 mm. wide] on each forewing), or two unmarked moths were placed. Moreover, each jar contained a fresh leaf of red currant (finally also [at intervals] droplets of condensed water). A summary of the experiment is given in table 12. It will be seen that the length of life averaged about 11½ days, both in the marked and in the unmarked adults.

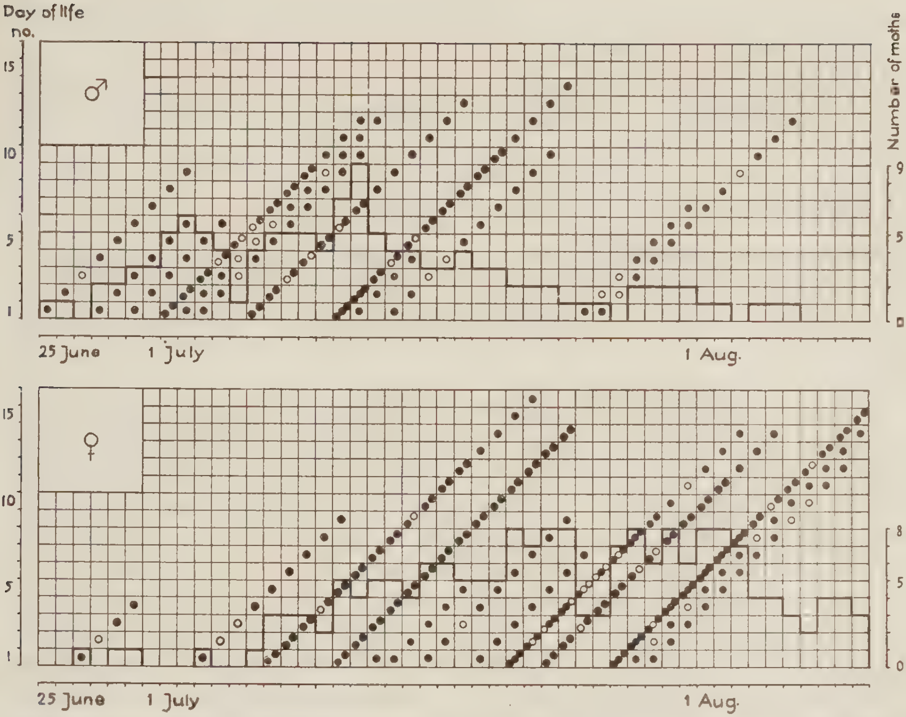


Fig. 17. Adult population of *Pandemis heparana* in cage *b*, Åkarp 1953. For further explanation see fig. 16 and text.

The experiments with marked moths prove that adults, on many of the examinations in cage *b*, were overlooked. This is illustrated by fig. 16, which shows the known occurrence of adults of *Spil. ocellana* in cage *b*, 1953; also by fig. 17, which shows the equivalent for *Pand. heparana*.

The meaning of some terms used in the text of fig. 16 appears from the following:

The number of *direct observations* corresponding to one and the same adult is equal to the number of days on which the adult was observed in the cage. The observation of the adult on the first of these days represents one direct observation, etc. Similarly, the number of *inadvertences* corresponding to one and the same adult is equal to the number of days on which the adult was overlooked. Each proved inadvertence represents one *indirect observation*. This is referred to the day when the inadvertence happened.

As an example should be mentioned that one of the males of *Spil. ocellana* was observed in the cage each day from June 28 to and including July 11 — not, however, on July 5, 9, and 10. In this case the number of direct observations is 11 and the number of indirect observations 3, the latter corresponding to July 5, 9, and 10 respectively.

The black circles in figs. 16—17 show the distribution of the direct observations, the white circles the distribution of the indirect observations. Concerning

each adult the first day of life (day of life no. 1) is considered to be the day when the adult was first recorded.

The first observation and the last observation of each adult are of course direct observations. If, in the case of each adult, these two observations are omitted, the number of direct observations is to the number of indirect observations as 82 to 18 (*Spil. ocellana*), 84 to 16 (*Pand. heparana*), 90 to 10 (*Cac. rosana*) and 80 to 20 (*Acl. reticulana*).

Certainly, the above figures refer to the experiments in cage *b*, 1953, but no doubt adults were overlooked also on examinations made in cage *b*, 1952, in cage *a*, 1952, etc. With regard to the studies on the annual period of flight, however, the error caused by the inadvertences is of little importance. Unless otherwise stated, it is supposed in the following pages that adults were never overlooked.

The competition between the larvae, e.g. for suitable feeding places, was no doubt hard in the cages, much harder than is usual under natural conditions. It is highly probable that the mortality of the larvae, as a consequence of the competition, was increased considerably above the normal. In the emergence experiments about 66 per cent of all specimens placed in the cages died already in the larval or pupal stage.

Table 13 shows the number of adults (fruit leaf tortricids including *Recurvaria*) in the emergence experiments. A total of 1,124 specimens representing twelve species occurred. The three most abundant species were *Acr. naevana* with 303 specimens, *Cac. rosana* with 154 and *Spil. ocellana* with 150 specimens. *Acl. holmiana* and *Cac. xylosteana* gave the smallest numbers, only 8 and 5 specimens respectively. In most of the species the number of females differed but little from the number of males.

It will be seen in table 13 that in 1953 *Cac. lecheana* and *Arg. variegana* emerged in considerably larger numbers in cage *c* than in cage *a*. This difference could be connected with the times when the larval material for the cages had been gathered. About 800 of the larvae (tortricids including *Recurvaria*) placed in cage *c* had been collected, as seen in table 11, fairly early in the spring, during a period (April 29—May 11) when few, if any pupae of *Cac. lecheana* or *Arg. variegana* yet occurred. The larvae (about 1,000 specimens) placed in the same year in cage *a*, on the other hand, had been collected later in the spring (May 15—June 1), at least most of them during the period when larvae of *Cac. lecheana* and *Arg. variegana* pupated. It is true that also all recorded tortricid pupae were collected and put into the cages. There are reasons to believe, however, that pupae to a proportionally much larger extent than larvae were overlooked on the trees from which the larval-pupal material was gathered.

It should be mentioned that *Cac. lecheana* and *Arg. variegana* emerged in occasional specimens not only in cage *a*, 1953, but also in cage *a*, 1952 (cf. table 13), as well as in cage *b*, 1952—1953 (cf. p. 188). Since the larval material for the cages in all these cases had been collected towards the end

Table 13. Number of adults (fruit leaf tortricids including Recurvaria) in the emergence experiments, Åkarp 1952—1953.

	1952		1953				Total		
	Cage *a*		Cage *c*		Cage *a*				
	♂	♀	♂	♀	♂	♀	♂	♀	% ♀
Acl. holmiana[1]	0	1	0	1	1	4	1	6	—
„ *reticulana*	2	5	8	1	34	43	44	49	53
Cac. podana	28	27	11	11	12	10	51	48	48
„ *xylosteana*	0	1	3	1	0	0	3	2	—
„ *rosana*	13	8	35	42	23	33	71	83	54
„ *lecheana*	3	2	16	26	1	1	20	29	59
Pand. heparana	8	16	15	7	15	8	38	31	45
„ *ribeana*	5	11	31	29	12	9	48	49	51
Arg. variegana	0	4	10	11	3	1	13	16	55
Acr. naevana	31	29	33	47	86	77	150	153	50
Spil. ocellana	39	51	16	12	18	14	73	77	51
Rec. leucatella	15	15	12	11	7	8	34	34	50
Sum	314		389		420		1 123		

[1] One specimen not sexed and therefore not included.

of the spring (cf. table 11), the figures from all the experiments support, or do not contradict at least, the views given above.

Table 13 shows that in cage *a* adults of *Acl. reticulana* were much more abundant in 1953 than in 1952. As illustrated by data on p. 188 the same is true of cage *b*. These circumstances seem to reflect a real alteration in the abundance of the species under discussion in the field. Observations in the field indicate that at Åkarp in the spring of 1953 larvae of *Acl. reticulana* occurred in considerably larger numbers than in the spring of the previous year.

However, as seen in table 13, *Acl. reticulana* gave in the experiments in cage *c*, despite the fact that these took place in 1953, occasional adults only. It is evident that this circumstance is connected with the times when the larval material for the cage had been gathered. Larvae (tortricids including *Recurvaria*) had, as can be seen in table 11, been collected and placed in cage *c* during two periods: fairly early in the spring and early in the summer. During the first of the two periods *Acl. reticulana* was represented solely by eggs and/or "newly hatched" larvae. The second period happened when numerous larvae of the same species had already left the trees for pupation in the soil.

Additional data of the emergence of the moths are given in figs. 18—19. Each adult is considered to have emerged on the day when first recorded. The temperature data, both those in figs. 18—19 and those given in the following discussion of the emergence periods (and also those in fig. 20), are according to a thermograph kept about 70 m. away from the cages, in

the screen shown in fig. 55. The accuracy of this thermograph is discussed on p. 260.

Fig. 18 illustrates the emergence of nine species in cage *a*, 1952. It will be seen that *Cac. lecheana* emerged in the middle part of June, *Arg. variegana* in the second half of June, and *Pand. ribeana* towards the end of June and early in July. *Cac. podana, Acr. naevana* and *Cac. rosana* emerged chiefly in the first half of July. *Spil. ocellana* and *Pand. heparana* showed a noticeably long emergence period covering most of July and a large part of August. *Acl. reticulana,* finally, emerged in August.

Fig. 19 illustrates the emergence of the same nine species in cages *a* and *c,* 1953 (also taking into consideration some of the species in cage *b,* 1953). As is to be expected, the nine species emerged in the same chronological order as in cage *a,* 1952. In most of the species, however, the peak of emergence occurred much earlier (up to about two weeks) in the season than in the previous year. Since the summer of 1953 was considerably warmer than that of 1952 this is only natural. The average temperature in each of the three summer months was as follows:

	1952	1953
June	13.6 °C	16.6 °C
July	15.7	17.5
August	16.1	16.6[1]

[1] Aug. 24 and 25 not included.

As seen in figs. 18—19, the females of several of the species showed a tendency to emerge somewhat later in the season than the males. In most cases, however, the difference in seasonal appearance between the sexes was inconsiderable.

Turning to the population experiments (cage *b*), all the species listed in table 13 and also one additional species (*Acl. variegana*) emerged. Regarding several of the species, however, only occasional adults occurred.

In *Rec. leucatella* the maximum number of adults simultaneously recorded in cage *b* was 18 in 1952, and 20 in 1953. For the different fruit leaf tortricids the corresponding figures are:

	1952	1953
Acl. variegana	2	2
„ *holmiana*	3	7
„ *reticulana*	2	35
Cac. podana	26	12
„ *xylosteana*	1	1
„ *rosana*	25	33
„ *lecheana*	2	1
Pand. heparana	19	13
» *ribeana*	4	16
Arg. variegana	1	4
Acr. naevana	61	105
Spil. ocellana	41	19

Fig. 18. Emergence of adults of some species in cage *a*, Åkarp 1952. Black areas = males. White areas = females.

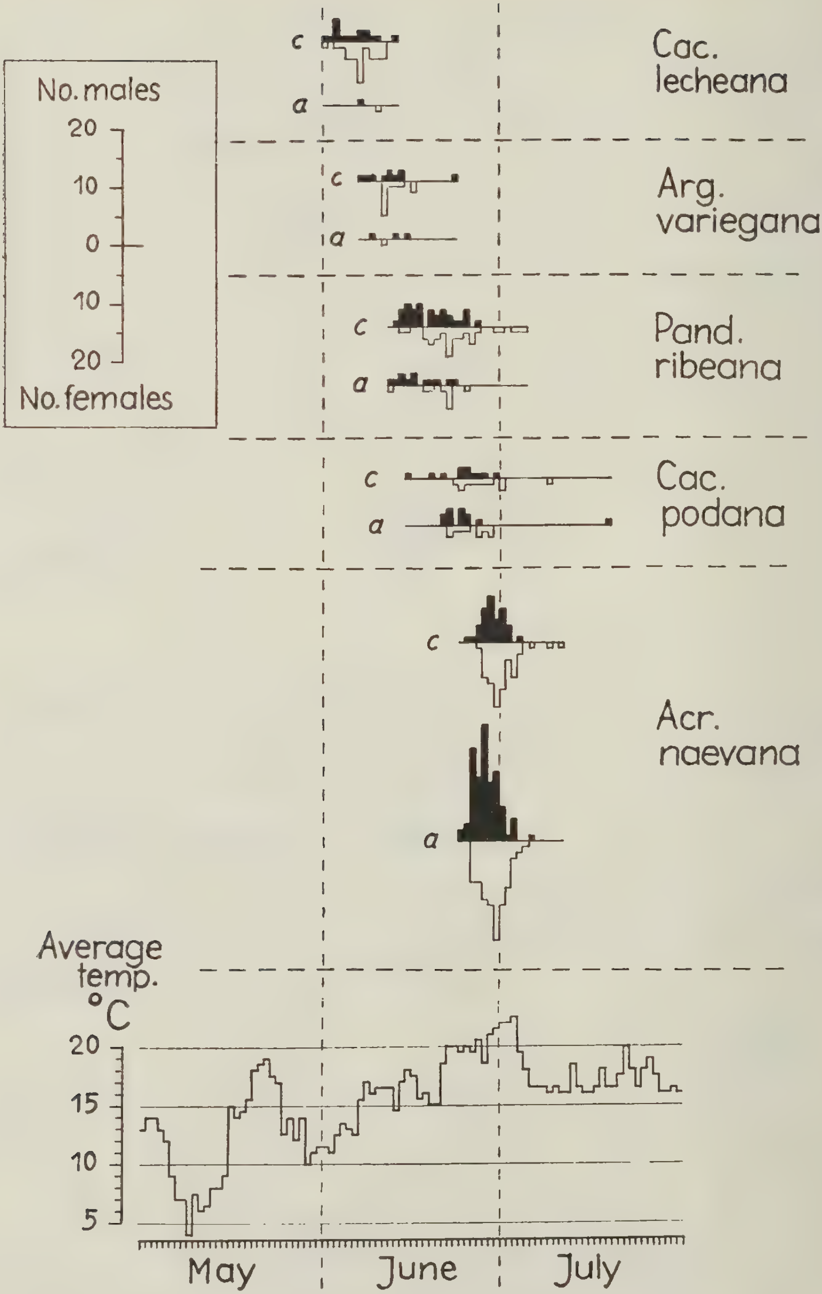
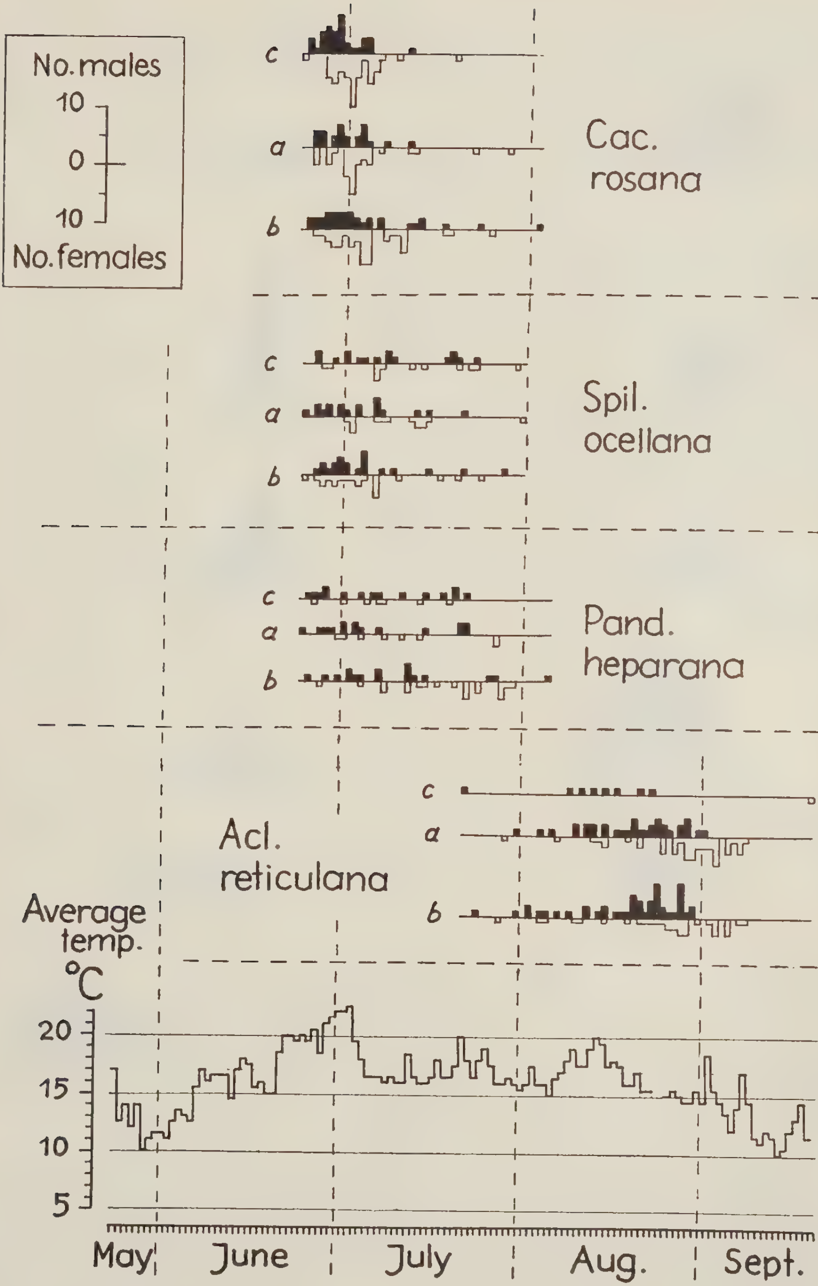


Fig. 19. Emergence of adults of some species, Åkarp 1953. Black areas = males.



White areas = females. *a* = cage *a*; *b* = cage *b*; *c* = cage *c*.

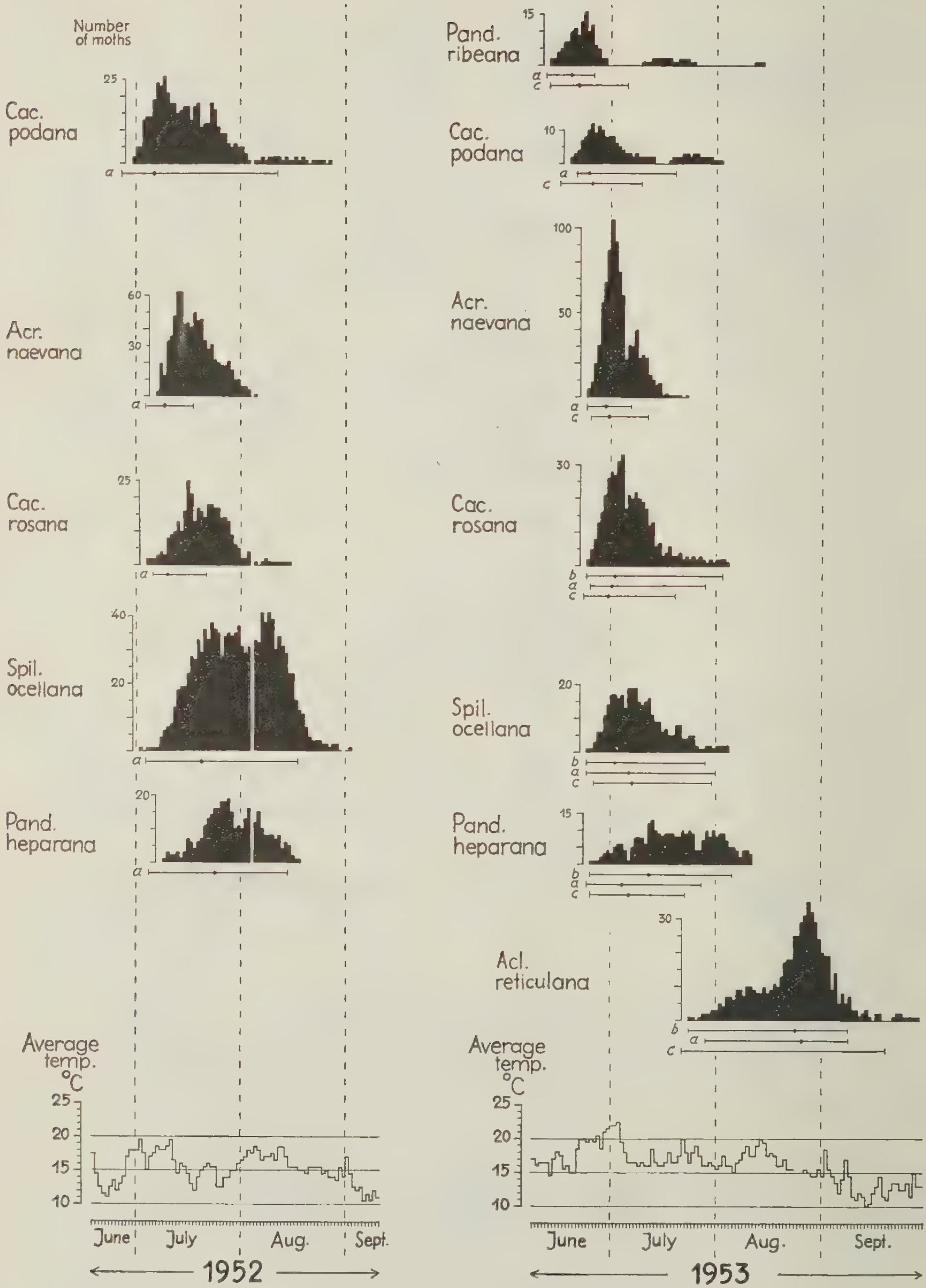


Fig. 20. Abundance of adults of some species in the population experiments (Åkarp, cage *b*). Left = five species in 1952. Right = seven species in 1953. As for lines *a*, *b* or *c*, see text, p. 193.

Fig. 20 shows the abundance of adults of some species in the population experiments, either during both 1952 and 1953, or *(Pand. ribeana, Acl. reticulana)* only during 1953. For comparison also data of the emergence periods in the different cages are given. Line *a* indicates the emergence period in cage *a*, line *b* in cage *b*, and line *c* in cage *c*. Black oval (on line marked *a, b* or *c*) indicates the date when the emergence of the first half of the total number of adults appearing was completed.

It will be seen in fig. 20 that in the population experiments *Cac. podana, Acr. naevana* and *Cac. rosana* in 1952 were chiefly on the wing in July, but in 1953 to a considerable extent as early as in late June. Also in *Spil. ocellana* and *Pand. heparana* the adult population largely appeared earlier in 1953 than in the previous year.

Figs. 16—17 give a good idea of the age distribution and the length of life of the adults of *Spil. ocellana* and *Pand. heparana* in the population experiments in 1953. It appears, for example, that the maximum length of life was about three weeks in *Spil. ocellana,* about two weeks in *Pand. heparana.*

The average length of adult life in the population experiments in 1953 was — first figure = males; second figure = females — about 5 and 7 days (*Cac. rosana*), 11 and 9 days (*Spil. ocellana*), 9 and 11 days (*Pand. heparana*), and 10 and 8 days (*Acl. reticulana*).

Daily rhythm

In this chapter an account of some actograph experiments on the flight activity is given first. Then some experiments on the egg-laying activity are discussed.

Flight activity.

An actograph is an apparatus that registers activity, e.g. the flight activity of insects. Backlund and Ekeroot (1950) have described an actograph for small terrestrial animals. The apparatus records the activity by means of electricity. It is complicated in construction and seems so far to have been tested only in preliminary experiments with *Calliphora.* Nielsen (1945) has introduced an actograph of considerably more simple design. The test animal is kept enclosed in a cellophane cylinder mounted on a rocking device. When the animal moves the cylinder swings, and this is registered by a pointer on a soot-covered paper attached to a rotating drum. Up till now the apparatus seems to have been tried only in experiments with adult insects. It was used by Nielsen in his studies on *Bembex,* later by Larsen (1949) in her studies on certain noctuid species.

At Åkarp an apparatus similar to that described by Nielsen was tested

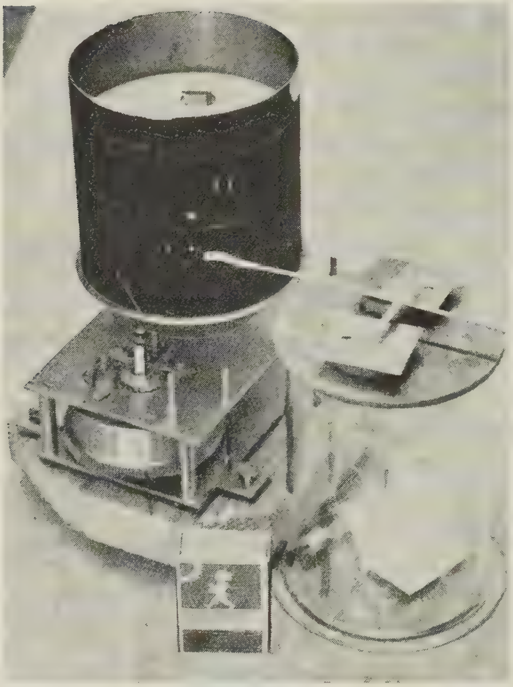


Fig. 21. View of actograph.

in preliminary experiments with fruit leaf tortricid moths. The results were disappointing, a fact which might have been the consequence of the low weight of the moths. The male of *Cac. podana,* one of the larger species (cf. fig. 2), weighs only about 12—19 mg.; the male of *Acl. holmiana,* one of the smaller species (cf. fig. 1), still much less, about 2 mg. For comparison also the weight of one male of *Rhyacia c-nigrum,* a noctuid used in actograph experiments by Larsen (cf. above), was determined and found to be about 125 mg.

It was considered probable, however, that an apparatus in which the moth when flying touches a sensitive balance device *from the outside* would be more effective. In collaboration with Mr Olov Hagström, mechanical engineer, Lund, this idea was developed and resulted in the apparatus shown in fig. 21. Later, it was used in numerous experiments and gave much information of the flight activity.

The moth is kept enclosed in a glass cylinder (11½ cm. high by 8 cm. wide) covered by a wooden disc. When flying the moth touches from time to time a cellophane cylinder (or a cellophane sail) hanging inside the glass cylinder, and thereby sets the former in motion. By means of a device consisting of two grass straws, one wooden stick and two needles (cf. fig. 22) the motion is transferred to a narrow and pointed piece of aluminium foil and

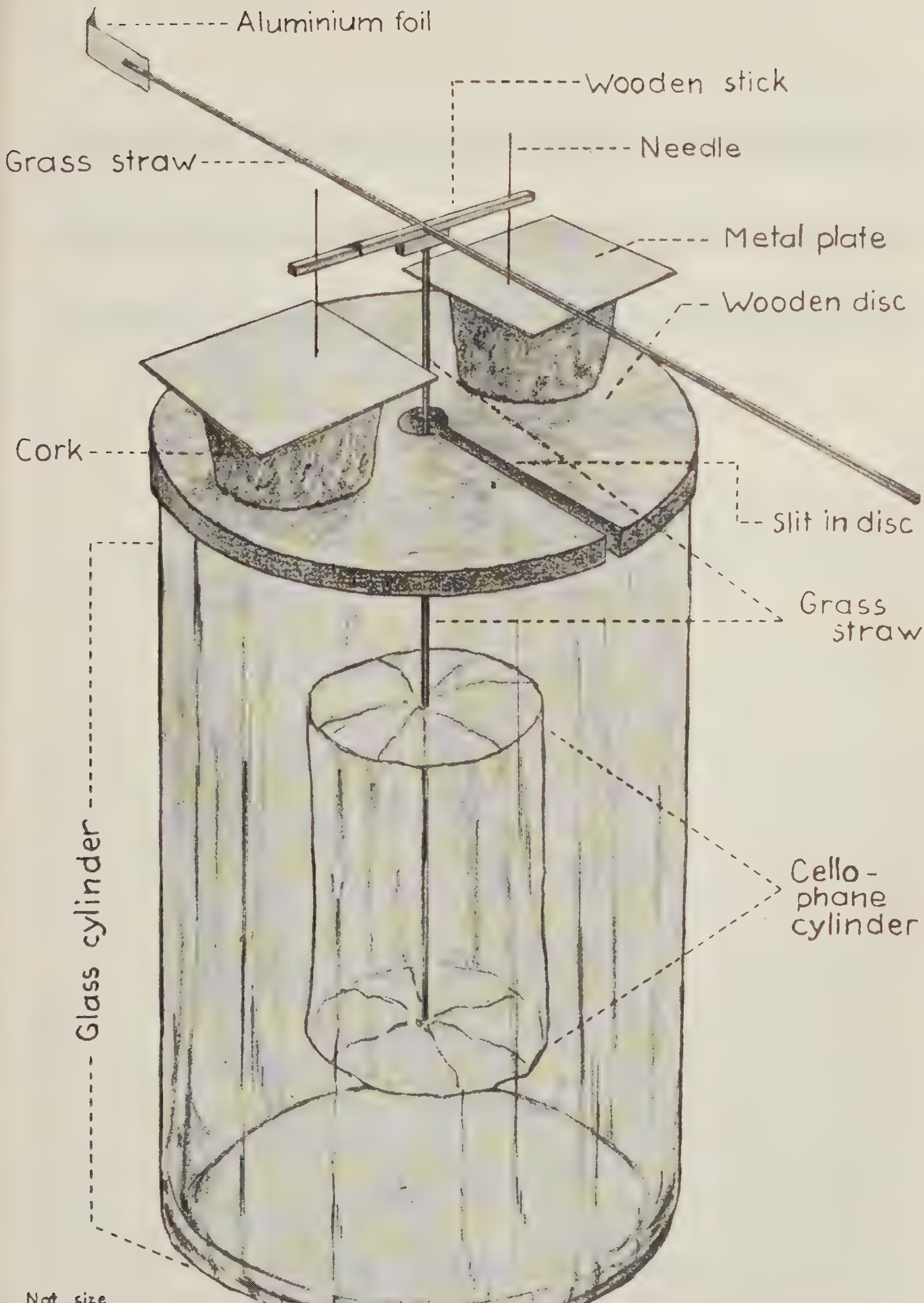


Fig. 22. Details of actograph.

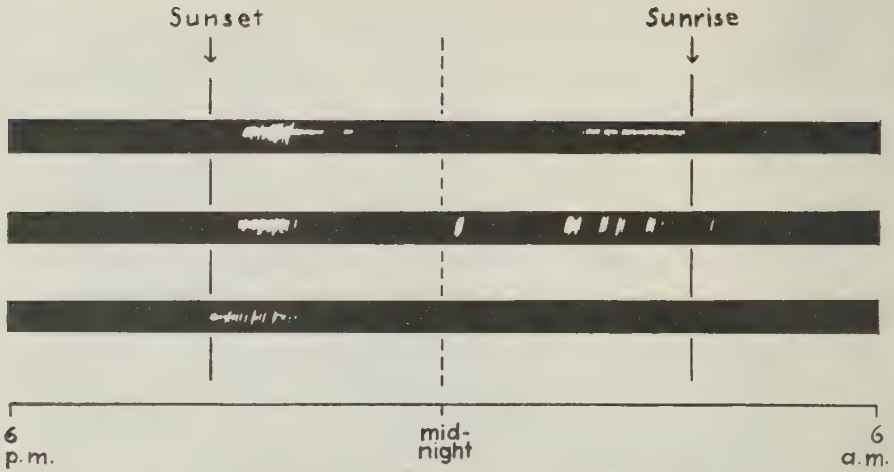


Fig. 23. Flight activity (*Argyroploce variegana*) in some actograph experiments carried out indoors, Åkarp 1953. Reproduction of original registrations.

Note: Unfortunately, the reproductions do not show the white, horizontal line made by the pointer of the actograph. On each of the original strips this line (which extends from left to right end of strip and connects the activity registrations) is clearly visible.

is registered on a soot-covered paper attached to a rotating drum. The latter makes a complete revolution in 24 hours.

When used indoors the apparatus is well adapted for studies on the activity of various tortricid species (and no doubt also for many other insects). However, in the case of the two smallest of the species tested, *Acl. holmiana* and *Acr. naevana,* the apparatus is not sensitive enough.

In some of the experiments it was observed that the moth now and then moved in one or the other direction without using its wings. At least in many cases, however, this sort of activity (walking or running activity) was not registered by the apparatus. It is assumed in the following that the moth was always flying when it set the balance in motion.

Only males were tested in the experiments accounted for below, one moth in each experiment. The moths were provided with water but never with food. Several actographs were operated simultaneously. One and the same moth was generally tested during several successive days.

In fig. 23 the original registrations in some of the experiments (*Arg. variegana*) are reproduced. Many of the registrations referring to other species are less marked and not adapted for reproduction.

Figs. 25 and 27 give information of the distribution of the activity among successive 15 minute periods, fig. 26 among successive 20 minute periods. Only during the periods indicated either by a horizontal line or by a black bar was the pointer continuously in contact with the soot-covered paper. During the periods marked with a horizontal line the pointer did not jump;

during each of the periods marked with a low black bar it did jump, but probably not more than 1—3 times (figs. 25 and 27) or 1—4 times (fig. 26); during each of the periods marked with a high black bar it jumped at least 4 times (figs. 25 and 27) or at least 5 times (fig. 26). In each of the experiments illustrated in the figures the moth remained alive in the actograph to the end of the experiment period.

Various fruit leaf tortricid species were tested indoors in 1953, in a room called the actograph room in the following. The room faced the east and was only illuminated by the light from the windows (never by light from artificial sources). Even in the middle of the day the light was diffuse and weak (cf. fig. 24). The temperature generally amounted to 22—23 °C and was never lower than 20 ° or higher than 25 °. The relative humidity usually amounted to about 50—60 per cent. It was never higher than 75 or lower than 40 per cent.

The results of some of the experiments in the actograph room appear from fig. 25. In *Cac. lecheana* the flight activity mainly occurred in the daytime but in the other species only or mostly in the night[1]. The activity was more or less concentrated to the early part of the night in some of the species, e.g. in *Pand. ribeana, Pand. heparana* and *Cac. rosana.* Two activity peaks, one in the early part and the other in the late part of the night, occurred in *Spil. ocellana*, also in *Arg. variegana, Acl. reticulana* and *Acl. variegana.*

Many data have been published indicating the relation between the daily rhythm of insects and the light conditions (cf. the reviews by Uvarov 1931). In actograph experiments undertaken by Larsen (1949) several noctuid species flew only in dark periods and a reversing of the light and the dark periods was accompanied by a reversing of the rhythm. Bentley, Gunn, and Ewer (1941) studied the beetle *Ptinus tectus* and obtained similar results.

The experiments in the actograph room indicate that the daily rhythm of the various fruit leaf tortricid species mentioned in fig. 25 is influenced by the light conditions. In order to test the relations more thoroughly a series of actograph experiments were carried out indoors in 1955. The actographs were only illuminated by electric light: by weak light (illumination close to the actographs about 1 lux or less) during some hours in the middle of the day (usually during five to six hours), otherwise by stronger light (illumination close to the actographs about 80 lux). In the continued discussion of the experiments the former period is called *the dusk period,* the latter period *the light period.*

As a light-source during the light period a clear, standard light bulb (100 watt, 220 volts) was used. It was mounted about 1½ m. directly above the

[1] The night is considered to start at sunset and to end at sunrise.

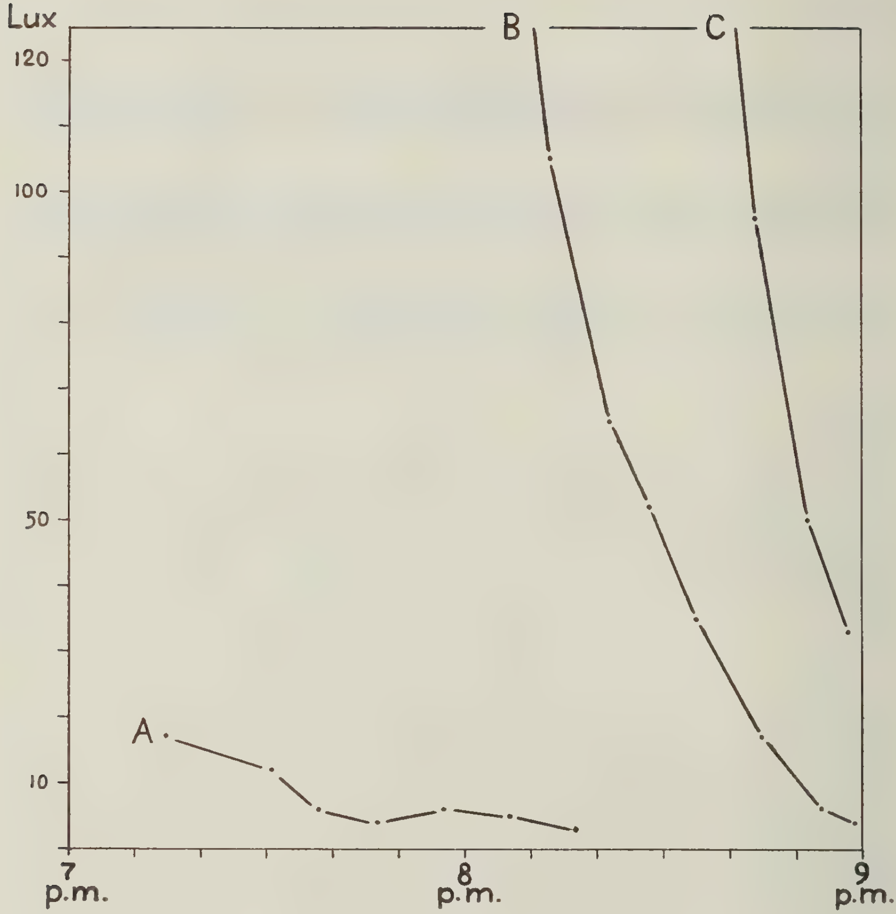


Fig. 24. Illumination according to measurements with a photometer (Ljuskultur AB, Stockholm), Åkarp, July 17, 1953. A = close beside an actograph in actograph room. B = below foliage of an apple tree in Substation orchard. C = in an open place in Substation garden.

actograph drum and was openly exposed, i.e. not covered by a lamp-globe or such-like. By means of a fan situated about 3 m. from the drum the air in the experiment room was continuously kept in circulation. On the same table as the actographs, about 4 m. from the fan, a bimetallic thermograph, a hair hygrograph, a dry-bulb and a wet-bulb thermometer were placed. Unfortunately no aspiration psychrometer was available.

In each experiment a male reared out-of-doors was used. Each moth was brought indoors in the afternoon. It was immediately placed in a glass

cylinder on the table mentioned above. Not until it had been kept there for a period of about 15—20 hours was it tested in the actograph.

Fig. 26 shows the results of the experiments with some of the species (*Pand. ribeana, Arg. variegana, Cac. rosana* and *Spil. ocellana*). It will be seen that the flight activity was strongly associated to the dusk period, also that the variations in temperature and humidity in the room were insignificant during the various experiment periods. The registrations clearly show that the light determined the rhythm.

In a few experiments *Pand. heparana* and *Cac. podana* were also tested. Frequently the moths flew in the dusk period but only occasionally in the light period.

Moreover, several experiments were made with *Cac. lecheana,* i.e. with a species mainly flying in the day-time in the actograph room in 1953 (cf. above). The tests took place in the middle of June, 1955, in a different room from that used in the experiments with other species made later in the same year, but under similar light conditions (weak light during some hours in the middle of the day, otherwise fairly strong light). The moths showed no regular rhythm, flying intermittingly both in the dusk and in the light period (frequently also in the night). No doubt the absence of a distinct rhythm was due to the abnormal light conditions.

The actograph apparatus described above is sensitive even to weak air movements and therefore far from ideal for use out-of-doors. A series of experiments with *Spil. ocellana,* however, made in a shady part of the garden in 1956, were successful. The apparatuses were situated about ¾ m. above the ground in a celluloid cage equipped with several ventilation slits. Even in the middle of the day the light was diffuse in the cage — stronger, however, than in the actograph room in 1953. The actographs were not exposed to artificial light.

Fig. 27 shows the results of the experiments made during the period July 18—26, 1956. The temperature curves are based on thermistor measurements (apparatus and methods the same as those mentioned on p. 181). The accuracy of the temperature figures lies between ± ½ °C.

As can be seen, the flight activity mostly happened late in the daytime and early in the night. In the three warmest of the eight nights, activity also occurred in the middle of the night. Unlike in the actograph room in 1953, there was no activity peak late in the night. It might be suspected that this was due to the temperature. During the periods when the moths were highly active the temperature generally amounted to 15—20 °C in the actographs. Late in the night the temperature was in most cases lower than 15 °, in two of the nights lower than 10 °.

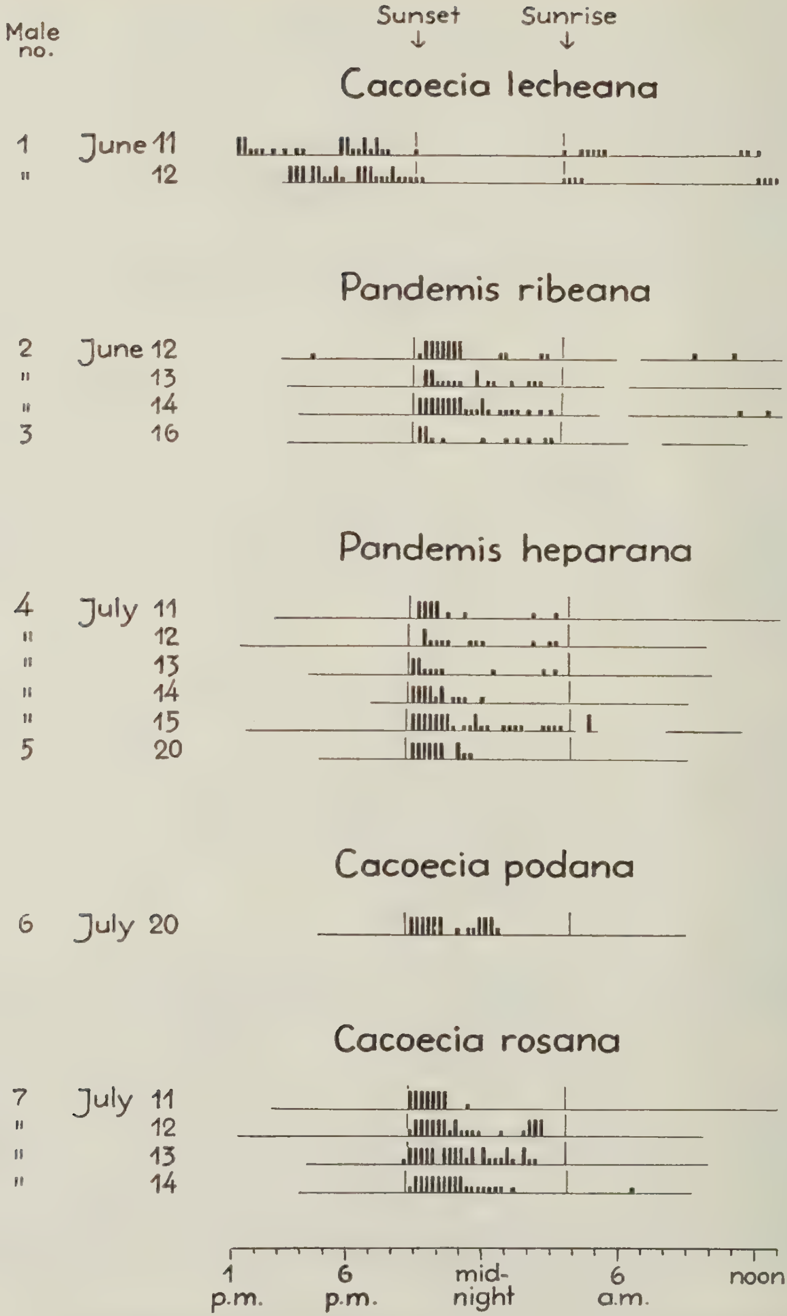
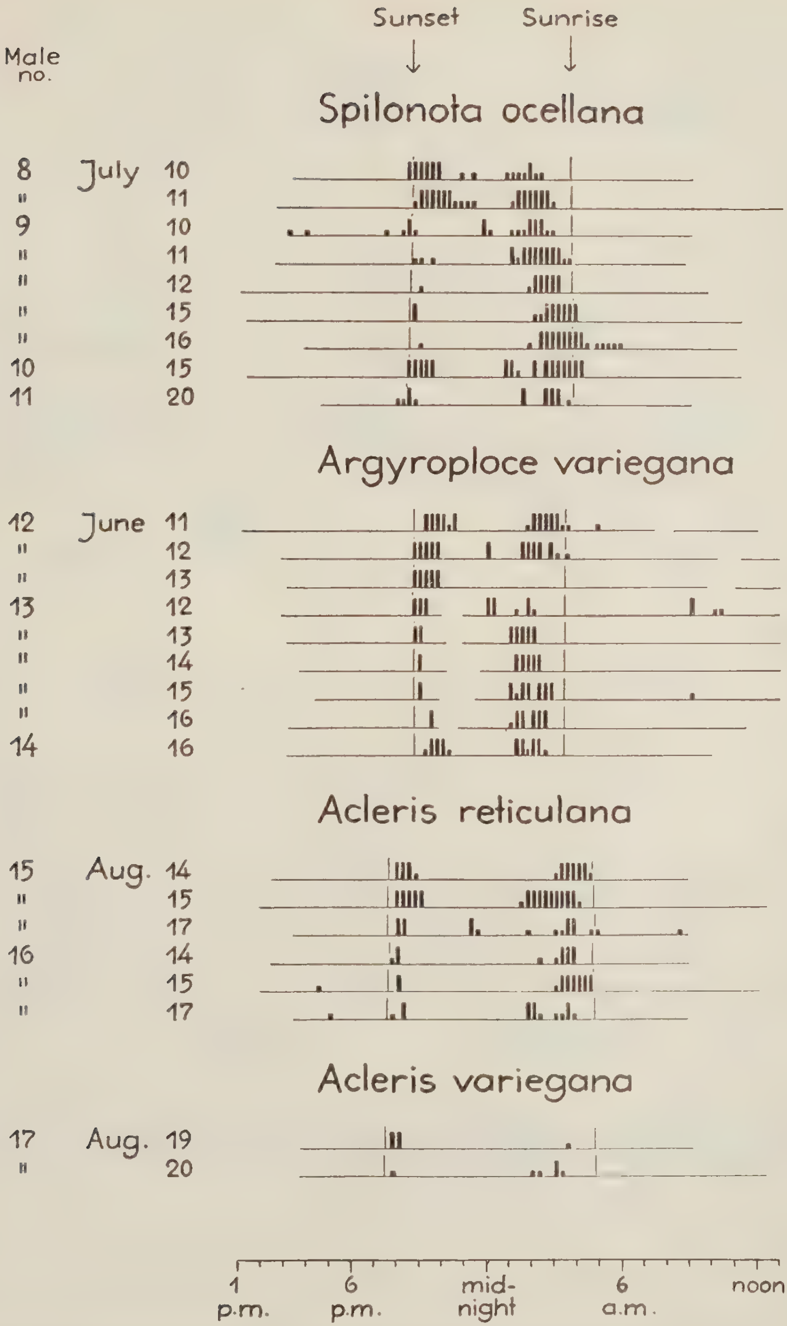


Fig. 25. Flight activity (black bars) in some actograph experiments in



actograph room, Åkarp 1953. For further explanation see text, pp. 196—197.

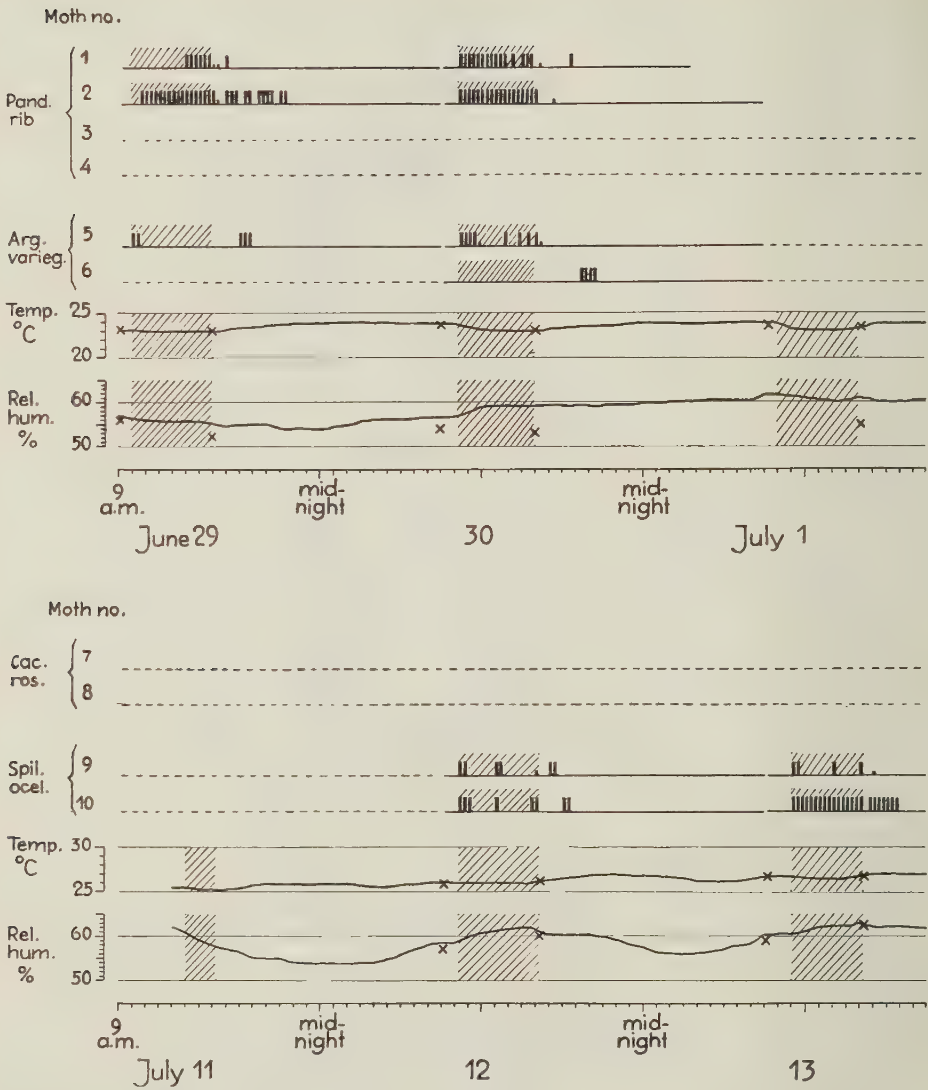
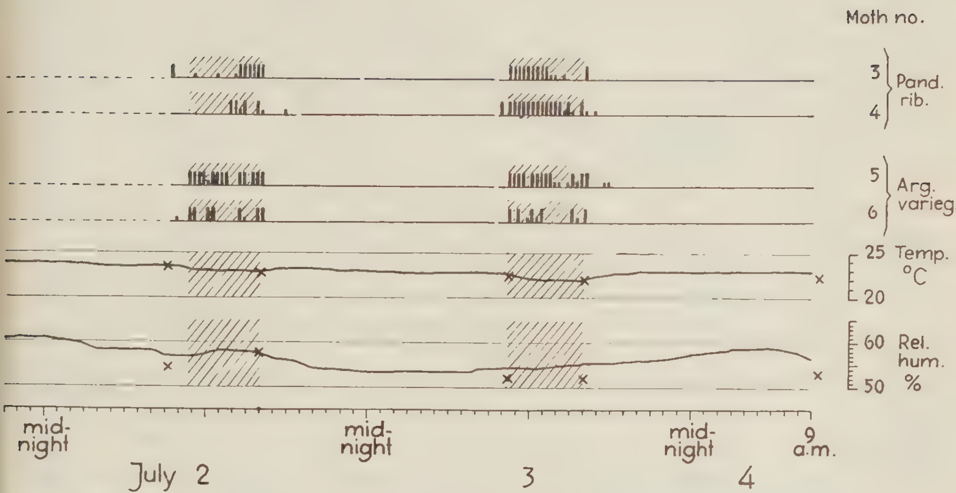
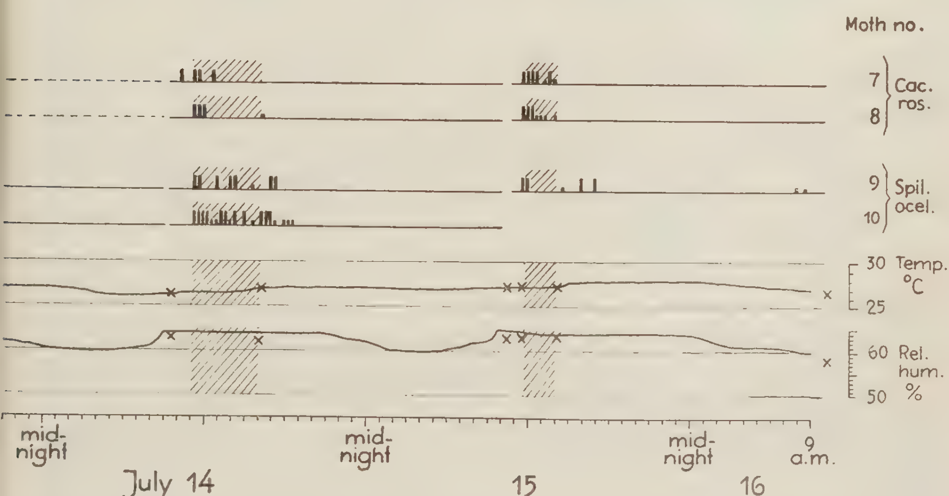


Fig. 26. Flight activity (black bars) in some actograph experiments indoors, cf. text). Period not indicated by diagonal lines=light period (fairly strong *Hum.;* curve=hygrograph; crosses=psychrometer.





Åkarp 1955. Period indicated by diagonal lines=dusk period (very weak light, light, cf. text). *Temp.;* curve=thermograph; crosses=mercury thermometer,

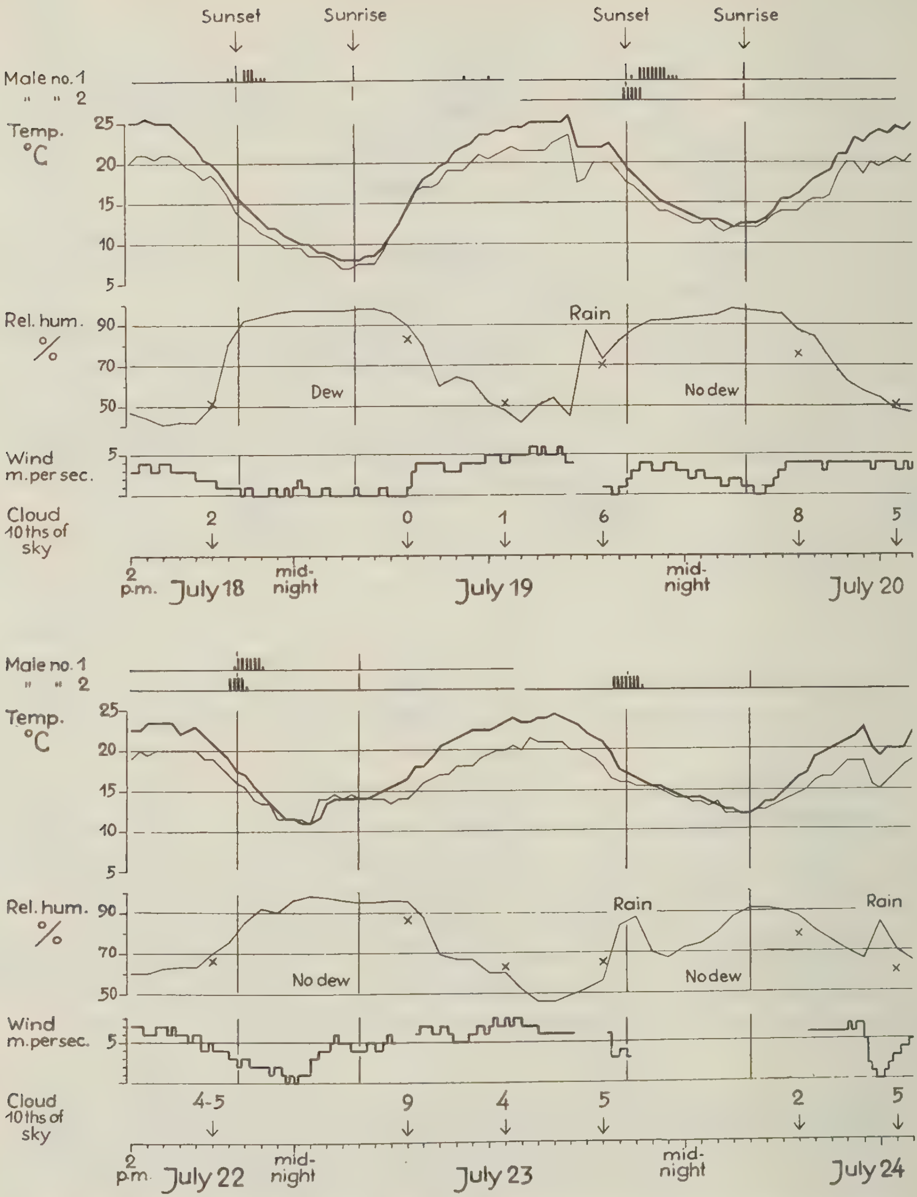
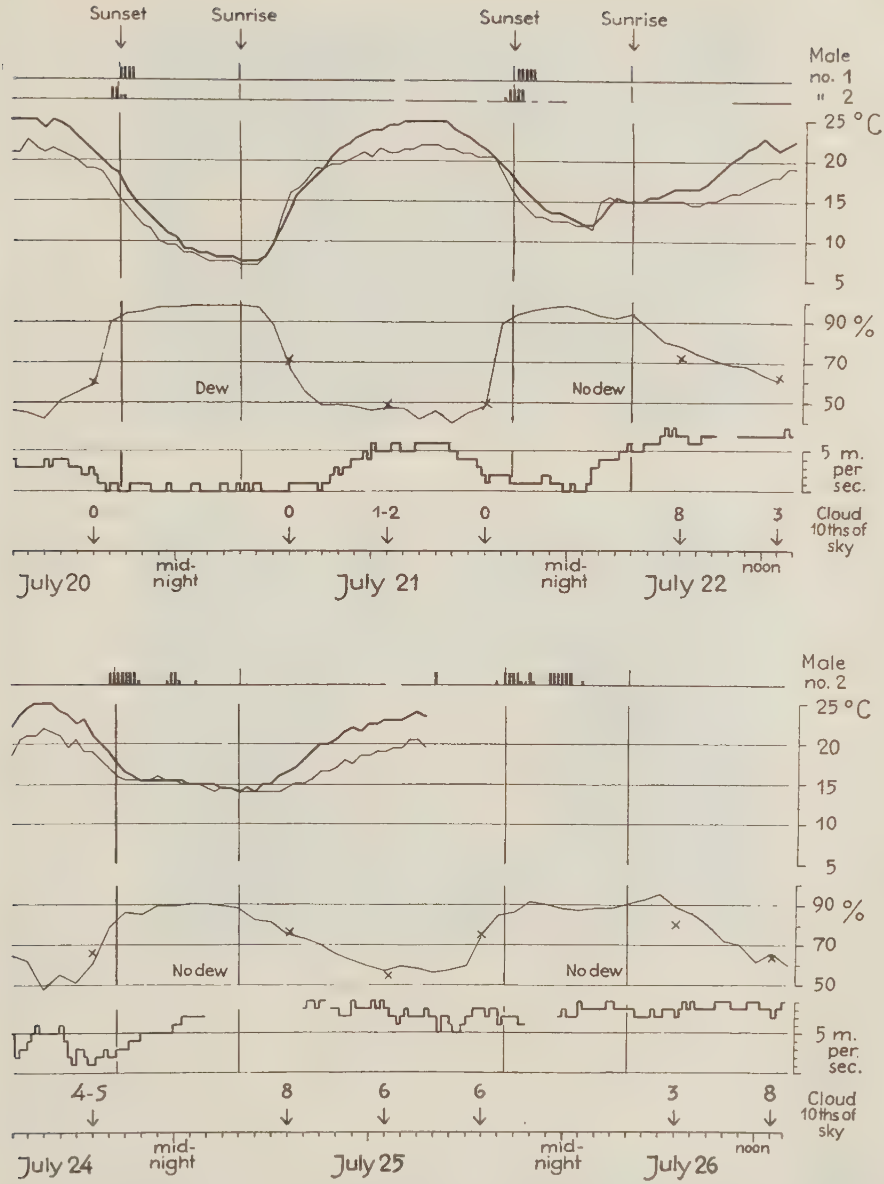


Fig. 27. Flight activity (black bars) of *Spilonota ocellana* in some actograph
Akarp 1956. *Temp.;* thick curve = thermistor in an actograph in the celluloid
away from the celluloid cage. *Hum.;* curve = hair hygrograph in the screen;
the screen. *Wind* = cup anemometer about 9 m. above ground. *Dew data* = dew
the celluloid cage.



experiments carried out in a celluloid cage situated in a shady place outdoors, cage; thin curve = thermistor about 2 m. above ground in a screen about 25 m. crosses = Assman psychrometer in open air, about 2 m. above ground, < 3 m. from recorder (W. Lambrecht) in open air ¼ m. above ground, about 30 m. from

Egg-laying activity.

Concerning the time of day when egg-laying occurs in the different fruit leaf tortricid species recorded at Åkarp, no studies in a proper sense seem to have been carried out by other workers. It can be suspected that this is connected with the difficulty in studying the egg-laying in the natural habitats of the moths. To discover ovipositing females in the field is indeed far from easy.

In some experiments at Åkarp in 1956 the hourly distribution of the egg-laying activity in some of the species was studied. From various points of view the experiments are of a preliminary nature and the results cannot be generalized. Particularly the methods used, hovewer, seem to be of interest.

Before discussing the above experiments, it should be mentioned that females of different fruit leaf tortricids were kept confined in bags containing apple shoots in some experiments in 1955. Some of the bags consisted of nylon net, other bags of cellophane. The moths deposited eggs frequently; in the net bags always on the apple shoots but in the cellophane bags chiefly on the cellophane. These observations gave the idea of the egg-laying recording apparatus shown in figs. 28—29. The apparatus was built in 1956 and was used in all experiments on the egg-laying activity performed in the same year.

In the apparatus the moths are kept in either of two nylon net cages. Each of the two cages (which are called net cage A and net cage B below) measures $7 \times 7 \times 7$ cm. The nylon material is white with a mesh size of about 1½ mm. In each cage two narrow horizontal slits have been cut. These two slits are between 6½ and 7 cm. long and situated opposite each other immediately under the top cover of the cage (cf. fig. 28).

As shown by measurements (kindly made by Egon Hansson, Associate Professor, Alnarp) with a Beckman spectrophotometer, the above-mentioned net transmits a large proportion of the light. With regard to each of the wave-lengths tested (310 mμ, 600 mμ, and 1,200 mμ), the percentage transmission, when the light is falling at right angles to the net, lies between 70 and 80.

A transparent plastic strip, 6½ cm. wide by more than 3 m. long, is also used. In preparing the experiments the strip is first wound round a trundle. After the outer part of the strip has been passed through the slits of the net cages, a piece of string is attached to its free end. The string is now led through a wooden tunnel and fixed to the side of a cylinder mounted on a turntable.

An electric motor is controlled by an electric clock-work and turns the turntable including the cylinder at hourly intervals, each time 30 degrees. The duration of the movement during each change is about 1½ seconds. As a result of the change a part of the string is wound on the cylinder and the plastic strip thus moves.

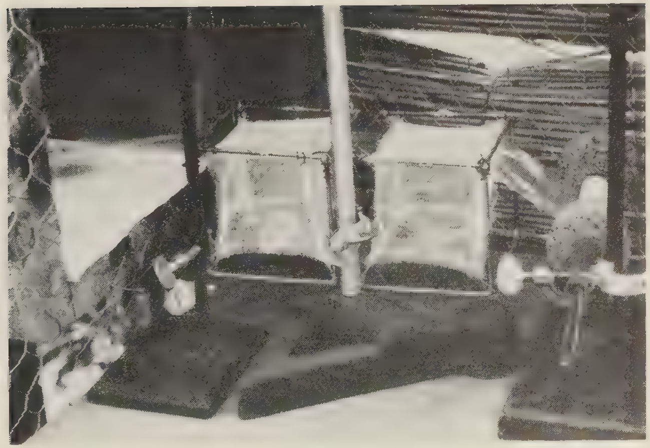


Fig. 28. The egg-laying recording apparatus. Above. The trundle, the plastic strip and the nylon net cages. Below. The turntable with the cylinder (note the string attached to the side of the cylinder). For further explanation see text.

Strictly speaking the interval between two successive changes varied between about 55 and 67 minutes. During each 24 hour period, however, the average length of the interval was almost exactly 60 minutes. Generally at least, the turntable turned less than 10 minutes before or after the intended time. No notice of the error caused by the variations is taken below.

The plastic strip is marked off into a number of sections. During the first hour of the experiment period the first section was always exposed in net

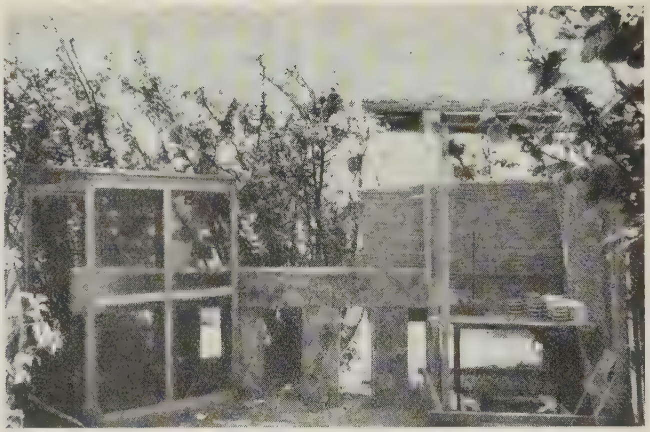


Fig. 29. From the experiments with the egg-laying recording apparatus, Åkarp 1956. To the right shelter, in wich the trundle and the nylon net cages were kept, in the middle the wooden tunnel, to the left a shelter containing the turntable etc. Photograph taken from the north.

cage A and the second section in net cage B, during the second hour the second section in net cage A and the third section in net cage B etc.

Before used in the apparatus the females were kept together with males in cloth bags on apple trees in the garden. There was never more than one moth pair in one and the same bag. Not until the female had deposited a number of eggs was it tested in the apparatus. Males were not kept confined, either in net cage A or in net cage B. None of the moths used in connection with the experiments was provided with water, nor with food.

There are no observations indicating that the females were damaged in the net cages, e.g. when the plastic strip moved. In several of the experiments one or several females laid eggs, apparently always on the plastic strip. As far as is known, all eggs remained on the strip to the end of the experiment period.

During the separate experiment periods either one or two species were tested. In the former case all moths were kept in one of the two net cages, in the latter case the moths of one species in one cage, those of the other species in the remaining cage.

By counting the eggs occurring on the different sections of the strip, data of the hourly distribution of the egg-laying activity were obtained. Before the start of a new experiment the eggs were removed from the strip.

The two net cages were situated in a shady place in a shelter mounted in the garden. The southern side of the shelter consisted partially of mats of reeds. Otherwise the walls of the shelter were made up of wire netting

(mesh size about 3 cm.), the roof of a frame-glass lid. The arrangement of the mats etc. can be seen in fig. 29.

From July 12 to 25 also a third nylon net cage, of the same kind as those mentioned above, was in use in the shelter. Neither was this cage (net cage C) exposed to the sun. All net cages were held by means of stands a few cm. above a table, their height being about ¾ m. from the ground.

During the above period (July 12—25) a record of the temperature in net cage C was kept. A thermistor was used and the measurements were made by employing the same methods as those described on p. 181. The accuracy of the temperature figures obtained lies between ± ½ °C.

The hourly distribution of the egg-laying activity in some of the experiments can be seen in fig. 30 (*Spil. ocellana*) and fig. 31 (*Cac. podana*). The temperature curves are based on the thermistor measurements mentioned above.

To begin with *Spil. ocellana,* a total of 385 eggs was recorded (July 11 —29). Only 13 (or 3 per cent) of these eggs were deposited from midnight to noon, but 50 (or 13 per cent) from noon to 3 p. m., 116 (or 30 per cent) from 3 to 6 p. m., 149 (or 39 per cent) from 6—9 p. m. and 57 (or 15 per cent) from 9 p. m. to midnight. Most of the eggs at least were laid at temperatures varying between about 15 and 23 °C. During the nights on which no eggs were deposited (cf. fig. 30) the temperature was less than 15 ° throughout or almost throughout the period from sunset to sunrise. It can of course be suspected that the absence of egg-laying activity during these nights was a consequence of the low temperature.

Turning to *Cac. podana,* only nine egg batches were recorded. As will be seen in fig. 31, all batches were deposited in the period from 6 p. m. to midnight, most of them in the first half of the night.

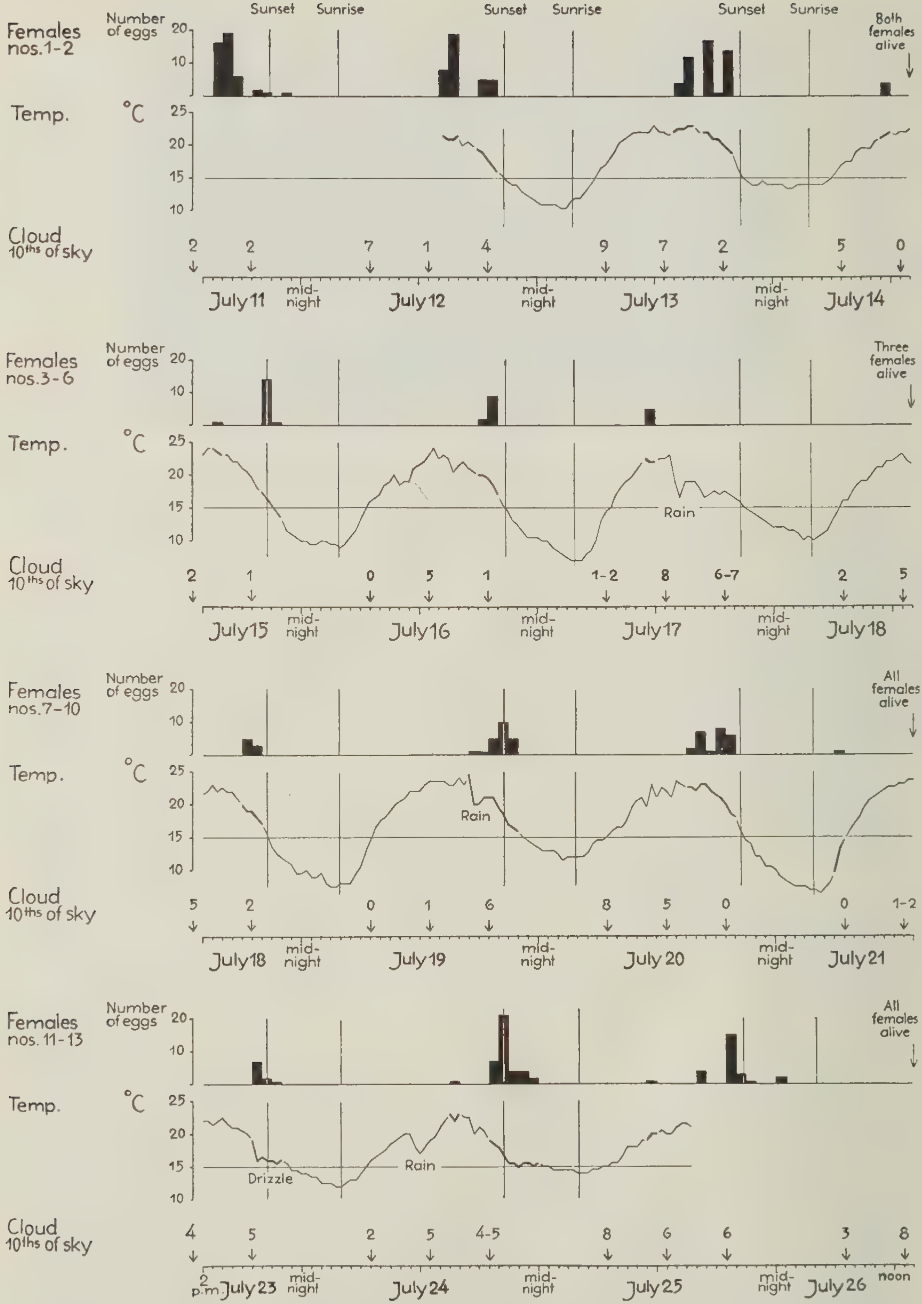


Fig. 30. Results of some experiments with *Spilonota ocellana* in the egg-laying recording apparatus, Åkarp 1956.

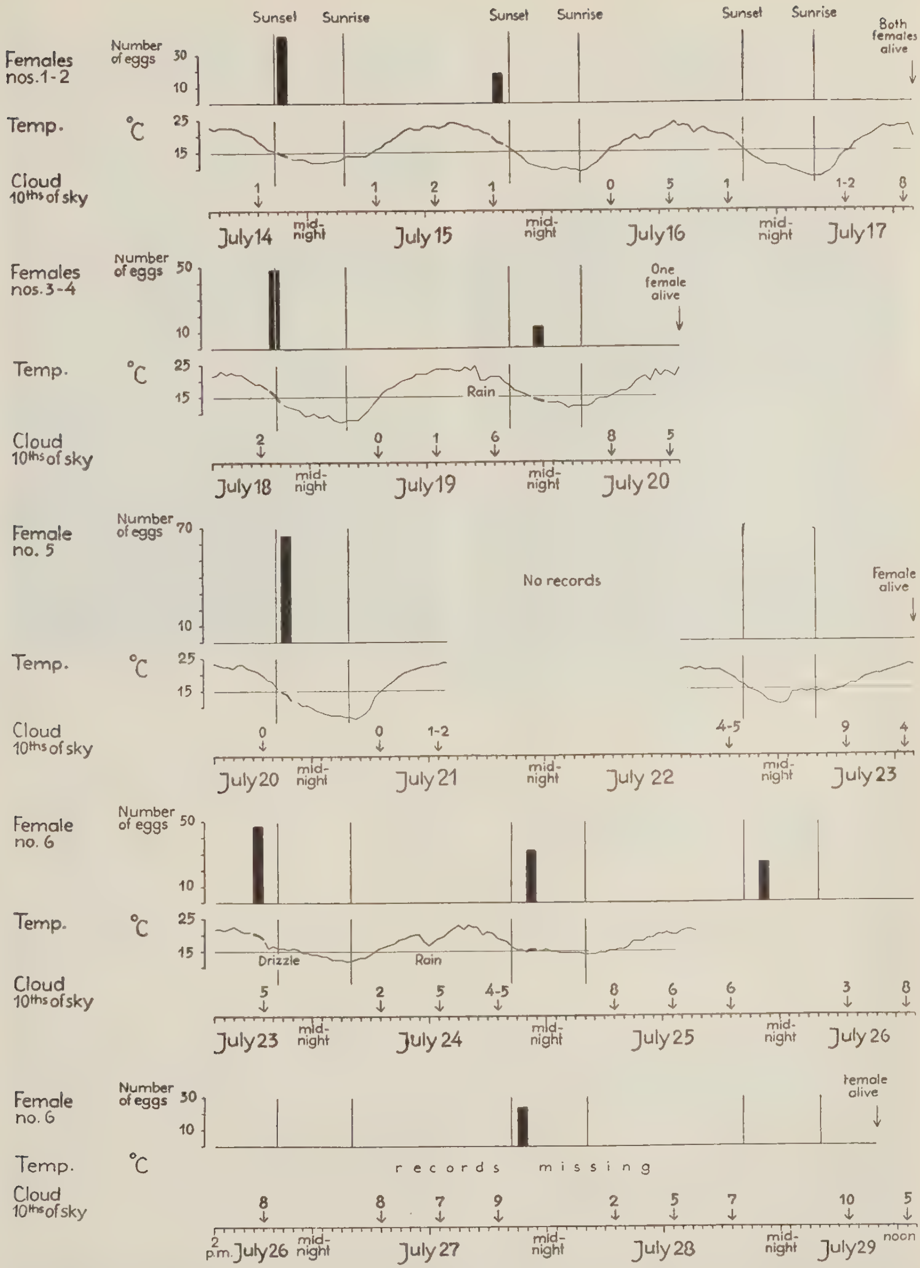


Fig. 31. Results of some experiments with *Cacoecia podana* in the egg-laying recording apparatus, Åkarp 1956.

Light trap experiments

Traps used by other workers

Before discussing the trap experiments made in connection with the fruit leaf tortricid studies at Åkarp, it would be well first to mention some types of traps used by other workers. Three kinds of traps for insects merit attention: the rotary net, the bait trap, and the light trap.

The *rotary net* is an electrically driven trap. The insects are captured in one or two nets mounted on a rotating boom. An example of a rotary net has been described by Williams and Milne (1935).

To the *bait trap* the insects are lured by one or several chemical attractants, to the *light trap* by artificiell light. Many models of both kinds of traps have been constructed (see e.g. Eyer 1937; Bobb, Woodside, and Jefferson 1939; Dethier 1947; Herms 1947).

As yet, the rotary net seems to have been tried only by few workers. Barnes, Fisher, and Kaloostian (1939) present data based on the catch from a rotary net which indicate the daily rhythm of flight activity in the raisin moth, *Ephestia figulilella*. Alexander and Carlson (1943), in studies on the codling moth, *Laspeyresia pomonella,* tested a rotary net and bait traps; both types of traps were simultaneously operated in an area less than 125 × 125 m.; the catch figures from the net show a noticeably close correspondence to those from the bait traps.

Bait traps have been successfully used by a large number of workers. Parrott and Collins (1934) compared in a study on *Laspeyresia pomonella* the efficiency of bait traps and light traps; they found both kinds of traps to be well adapted for investigations on the seasonal appearance of the moth.

Extensive experiments have been made with light traps, e.g. by Williams (1935, 1936, 1939, 1940). Of the fruit leaf tortricids Theobald (1926) obtained several species in light trap experiments, some of them in fairly large numbers. On the basis of light trap experiments Collins and Nixon (1930) studied the seasonal appearance of *Spil. ocellana*. In Holland a team of workers recently used light traps in studies on various fruit leaf tortricid species (see e.g. de Jong [1954]).

During the present investigations neither the rotary net nor the bait trap was tested. Instead, as has already been mentioned in the introduction (cf. p. 135), light traps were employed. For example, at Åkarp in 1951—1953 detailed studies with light traps were undertaken. The following account deals with these latter experiments, unless otherwise stated.

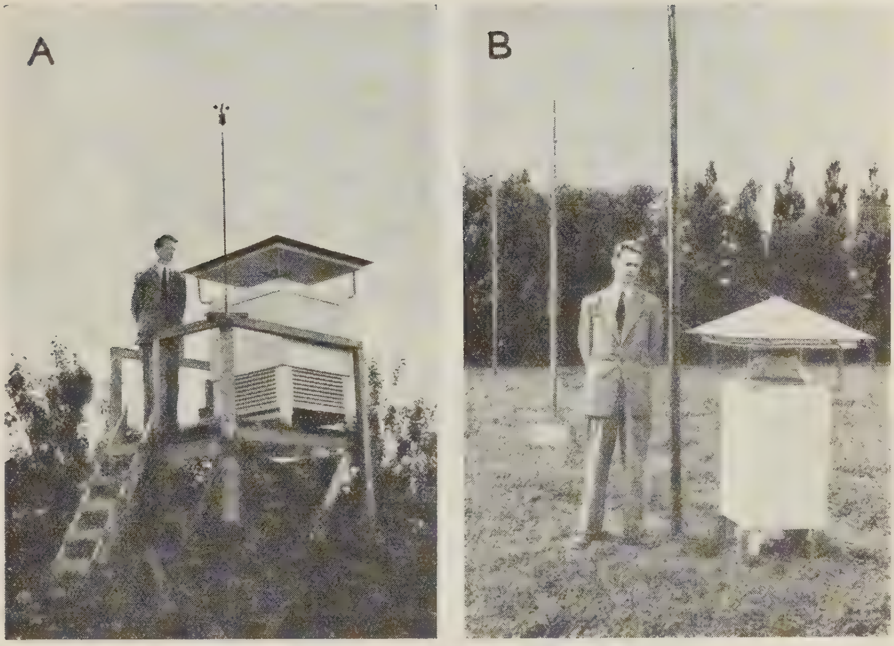


Fig. 32. From the light trap experiments, Åkarp 1952. A = trap A. B = trap B.

Apparatus and technique

At Åkarp two light traps were used, trap A and trap B. In both traps the catching mechanism is principally the same as in a trap described by Williams (1935).

Fig. 32:A gives a view of trap A, fig. 33 the principles of construction, and fig. 34 details of the same trap.

On a movable wooden square, which covers a circular opening in the ceiling and in the centre of which is an aperture for the lamp-holder, a current regulating device (cf. below) and an adjustable stand for the lamp-holder are mounted. By means of the stand the holder can be raised or lowered.

The lower portion of the light bulb hangs down into a movable glass device (cf. fig. 33) consisting of two parts, the interior part being a funnel about 14 cm. high, about 23 cm. wide at the top and about 6 cm. wide at the bottom. The exterior part, into which the interior part is loosely fitted, is a reversed funnel about 14 cm. high, about 22 cm. wide at the narrow end and about 46 cm. wide at the broad end. This reversed funnel rests on the top of a metal funnel (cf. fig. 33), the latter being about 18 cm. high and about 5½ cm. wide at the bottom. Below the metal funnel is a jar into

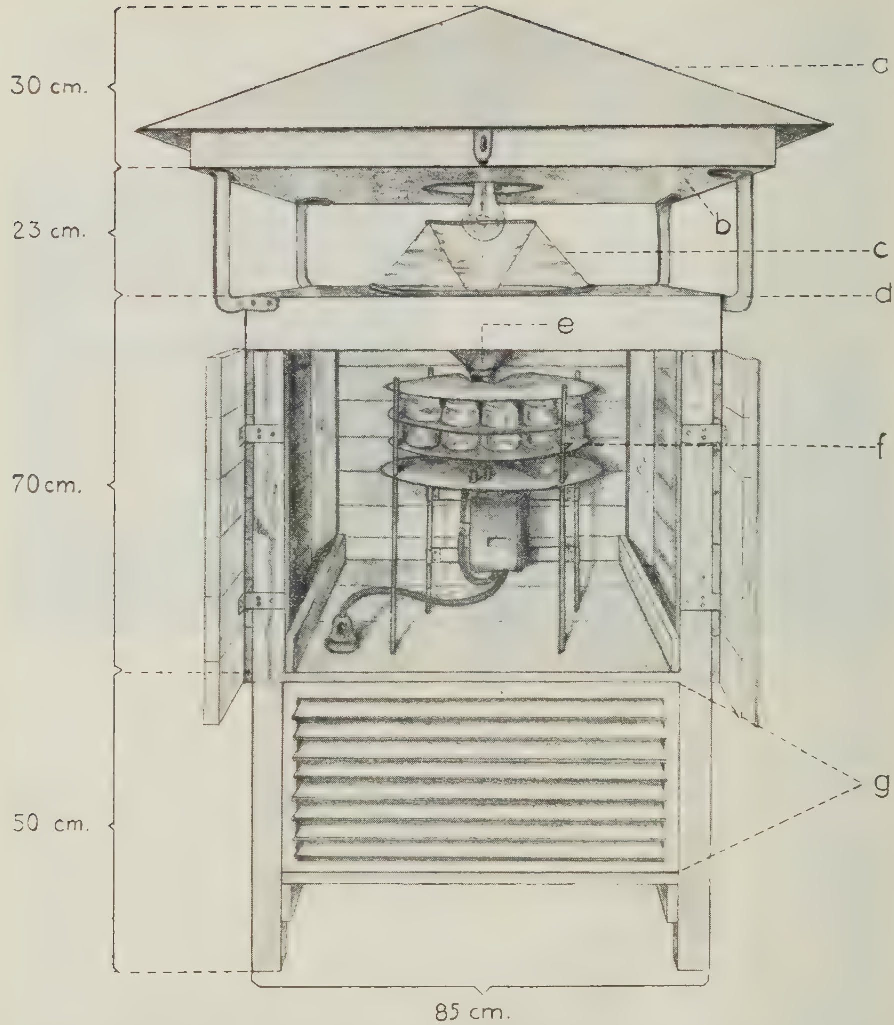


Fig. 33. Principles of construction of trap A. a= roof (iron-plate). b = ceiling (wooden square). c = glass device. d = iron bar. e = metal funnel. f = turntable with killing jars. g = shelter for meteorological apparatus.

which the insects fall. In the jar there is a vial equipped with a wick and containing chloroform.

During each of a large number of nights a *series* of jars was used in the trap. The jars stood on the turntable (cf. fig. 33) mentioned on p. 206, and were automatically changed, once an hour, in such a manner that they were exposed successively under the metal funnel. In the interval between

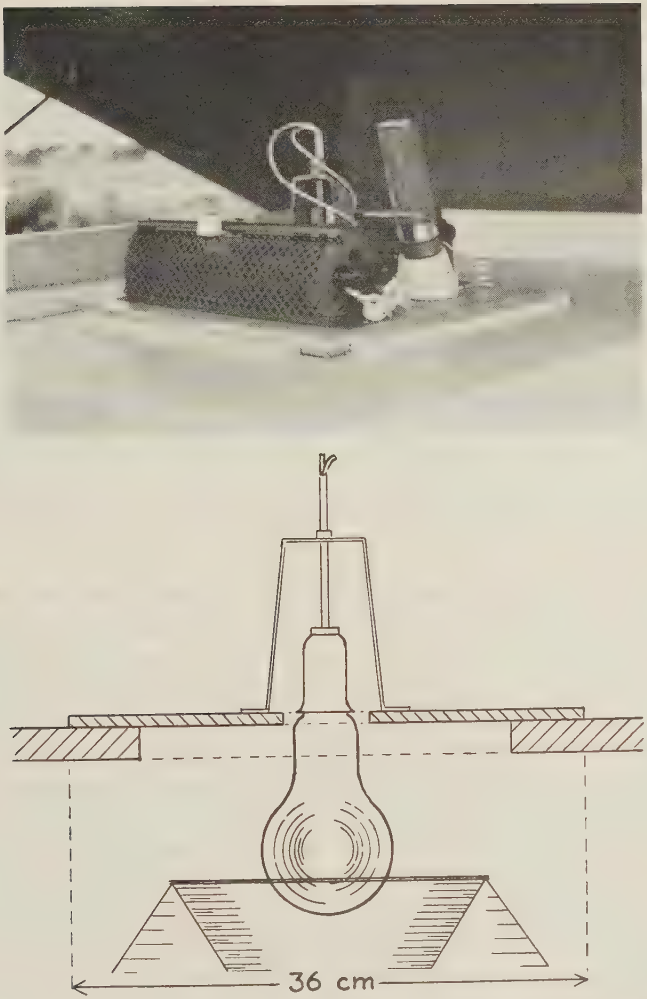


Fig. 34. Details of trap. A. Above. Current regulating device and stand for lampholder (former as well as latter mounted on a movable wooden square placed in the space between the roof and the ceiling). Below. Section showing light bulb, lamp-holder etc.

two successive changes all the jars, except the one exposed under the funnel, were covered by a cardboard lid.

Fig. 32:B shows trap B. There are no differences between the two traps with regard to the electrical equipment or the upper portion (glass device) of the catching mechanism. In trap B only *one* jar was used.

The lamp, in trap A as well as in trap B, was a clear standard light bulb

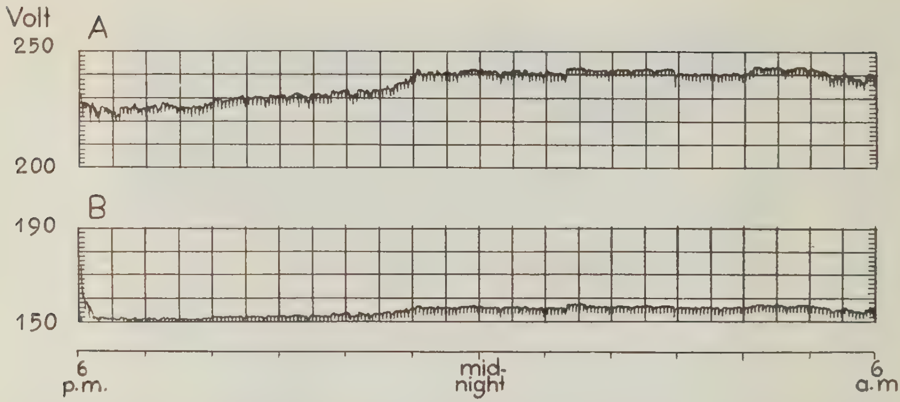


Fig. 35. Voltage during most of night of Oct. 9, 1953 (Plant Protection Substation, Åkarp). A = line voltage. B = voltage over light bulb in trap B. — According to registrations carried out by the Malmö Electricity Works.

Note: During the period when the record was kept a refrigerator was working in the Substation building. This possibly accounts for the notches in the curves. In discussing the curves in text the notches are not considered.

(200 watt, 160 volts). By means of an electric clockwork the current was switched on and off automatically. Late in September 1952, also late in September and early in October 1953, the traps were kept working from 6 p. m. to 6 a. m. (sunset occurring earlier than 6 p. m. and sunrise later than 6 a. m. at this time of the year). Otherwise they were operated (trap B during the experiments in 1951—1953, trap A during the experiments in 1952—1953) during the whole night, i.e. from sunset to sunrise.

A record of the voltage was kept during most of the night of Oct. 9[1], 1953. It will be seen from fig. 35 that in this night the line voltage changed considerably during the period 6—11 p. m., i.e. from about 222 to 239 volts. Later in the same night, during the period 11 p. m. — 6 a. m., the line voltage only varied between about 236 and 244 volts.

In each trap a constant resistance of 16 ohms (15 watt) and a ballast lamp (Standard G 1 S/7) were run in series with the light bulb; further a variable resistance of 1,800 ohms (20 watt) was run in parallel with the bulb. By means of this apparatus the voltage over the light bulb was kept at an average of about 155 volts. From the time when the current was switched on there was a delay of about 20—30 minutes before the voltage stabilized. Otherwise the voltage over the light bulb varied only slightly. As can be seen from fig. 35, an increase of the line voltage from 222 to 244 volts corresponded to an increase of the voltage over the bulb from about 151 to 157 volts.

It follows from the above that the changes in the flow of light caused

[1] Here, as in the following pages, the date of the night is considered to be the date when the night starts.

Table 14. Data of the flow of light from some of the light bulbs.

Light bulb no.	Total no. of hours in use in trap	Decalumen at 155 volts		Diff. in per cent of higher figure
		before period in trap	after period in trap	
1	500	280	253	10
2	336	284	258	9
3	336	285	257	10
4	278	289	273	6
5	278	289	273	6

Note: Light bulb no. 1 = Philips; nos. 2—5 = Luma.

by the voltage variations were fairly small. On an increase of the voltage from 151 to 157 volts the flow of light from the lamp increased by about 14—15 per cent.

The light bulbs were frequently changed. In 1951—1953 a total of 23 bulbs were used, viz. 4 (manufactured by Philips Ltd) in 1951 (in trap B), and 19 (Luma, manufactured by Lumalampan Ltd) in 1952—1953 (4 in trap A and 5 in trap B in 1952; 5 in trap A and 5 in trap B in 1953). Except in some tests on the flow of light (cf. below) the bulbs were only operated in the light trap experiments.

Before being used in the trap experiments one of the Philips bulbs and all the Luma bulbs were tested at 155 volts in a spheric photometer (by Lumalampan Ltd, Stockholm). The Philips bulb showed a flow of light of 280 decalumen. For the other light bulbs the figures varied between 281 and 289 decalumen. Thus, there were but small differences between the light bulbs investigated.

Some of the light bulbs were tested in the spheric photometer both before and after the period in the trap. The figures obtained are summarized in table 14.

Two of the Luma bulbs were working for about 370 hours each (Sept. 15 — Oct. 14, 1952), the remaining Luma bulbs for about 230 340 hours each. On the basis of the figures obtained in the spheric photometer it can be calculated that the capacity (measured in the flow of light at a given voltage) of each of the latter light bulbs decreased by about 5—10 per cent from the beginning to the end of the period in the trap.

Location and time of work

The Substation of the Swedish State Plant Protection Institute in Scania is located at Åkarp, about 2½ km. from the sea on the plain between Malmö and Lund (cf. map. p. 282), at lat. 55°39′ N. and long. 13°06′ E. The height above sea-level is about 10 m. The ground is a light moraine clay overlying limestone.

Fig. 36. From the light trap experiments, Åkarp 1952. Above. View of the two traps from the south. Left arrow indicates trap A, right arrow trap B. Below. View of trap A from the north.

In 1951 only trap B was operated. It was mounted on a wooden platform in the central part of the Substation orchard. The light bulb occupied a position about 4 m. from the ground.

In 1952—1953 both traps were operated. Trap A was mounted on the same platform and in the same place as trap B in 1951. Trap B was placed

about 45 m. farther to the east, directly on the ground in a neighbouring orchard (see fig. 36). In the former case (trap A) the light bulb was about 4 m. from the ground, in the latter case (trap B) about 1 m.

The catching place in the Substation orchard is called *catching place I* below. The catching place in the neighbouring orchard is called *catching place II.*

A brief description of the Substation area with surroundings follows. Of course the district altered, e.g. in its vegetation, from year to year. Unless otherwise stated, however, the data given below are valid for 1951, 1952, and 1953.

Fig. 37 shows the position and the size of the Substation area. In the northern part is a small plantation with the Institute building, in the southern part experimental fields for agricultural crops. The garden, covering an area of about 55 × 80 m., is located between the plantation and the fields.

The platform (at catching place I; cf. above) stood in the eastern half of the garden, in an orchard containing 90 trees (all planted in the spring of 1939). The position of the platform in relation to the trees appears from fig. 38.

On a triangular area close to the east and southeast of the Substation garden there was a vegetable garden during the summer of 1951. Trees were absent. Later, however, an orchard was laid out there, a total of about 500 trees (apple, pear, and plum) being planted, about 335 of them in the autumn of 1951, about 165 in the autumn of 1952. As mentioned above, trap B was exposed in this orchard (at catching place II), both in 1952 and in 1953.

In the vicinity north and east of the last-mentioned area there are several buildings, many of them surrounded by gardens with a varying number of fruit trees. Fig. 37 shows the distribution of the buildings as well as of the areas on which fruit trees occur.

From the north a rather large orchard reaches a point about 260 m. away from catching place I. This orchard contains more than 1,400 fruit trees (about 1,050 apple), all planted in 1947 or earlier.

Otherwise the Substation area is surrounded by expansive arable land, to the north as well as to the west and the south. Within a radius of 400 m. from catching place I there are no fruit trees and no buildings, either west or south of the Substation garden.

The distance from catching place I to the nearest permanent water body (a pond to the east; cf. fig. 37) is about 280 m. The corresponding distance to the nearest wood (Alnarpsparken, a decidiuous wood to the west) is about 900 m.

Trap A failed to work on three occasions (during the nights of Sept. 22

Fig. 37. Plant Protection Substation with surroundings, Åkarp 1953. Subst. = Substation area. Diagonal lines = fruit tree areas. Large circle = trap A (catching place I). Small circle = trap B (catching place II).

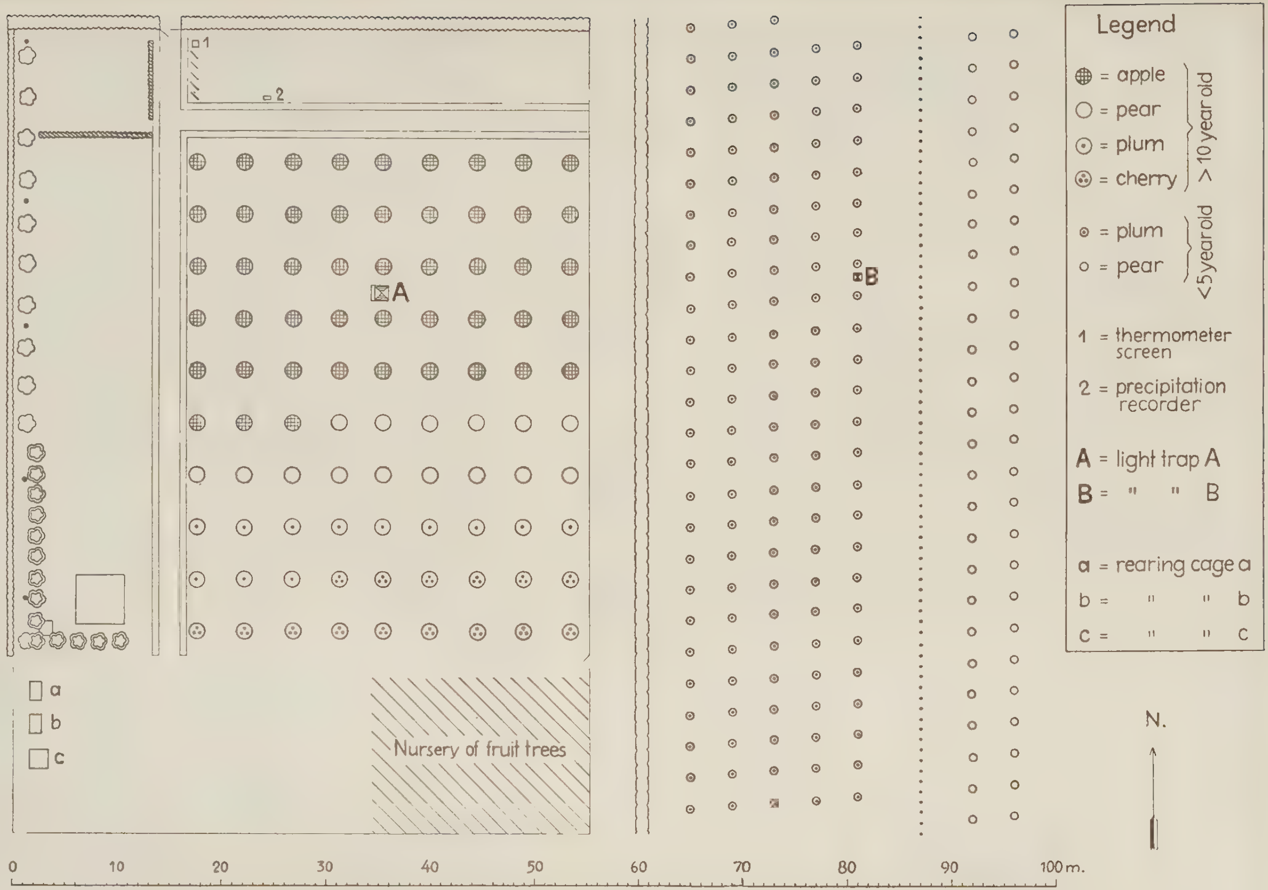


Fig. 38. Substation garden and part of adjoining orchard, Åkarp 1953.

Table 15. Distribution of the catch in trap A among different orders of insects; Åkarp, June 16—Sept. 15, 1952.

	June 16—30	July 1—15	July 16—31	Aug. 1—15	Aug. 16—31	Sept. 1—15	Total	Per cent
Diptera	14,282	15,829	4,641	53,342	17,576	2,214	107,884	92·7
Lepidoptera	314	815	636	3,011	782	170	5,728	4·9
Hemiptera	50	770	258	622	72	6	1,778	1·5
Hymenoptera	49	90	41	311	99	24	614	0·5
Coleoptera	16	36	20	92	15	3	182	0·2
Trichoptera	9	21	3	72	14	9	128	
Neuroptera	3	3	0	50	19	3	78	
Thysanoptera	0	0	4	17	0	0	21	0·2
Psocoptera	2	0	0	2	1	0	5	
Ephemeroptera	0	0	0	3	0	0	3	
	14,725	17,564	5,603	57,522	18,578	2,429	116,421	

and 28 in 1952, and Oct. 6 in 1953), trap B on four occasions (during the nights of June 14 and Aug. 10 in 1951, Sept. 28 in 1952, Oct. 6 in 1953).[1] Otherwise the traps worked continuously night after night during the following periods:

	Trap A	Trap B
1951	— — — —	May 17 — Nov. 8
1952	June 7 — Oct. 14	May 5 — Oct. 14
1953	June 1 — Oct. 9	June 1 — Oct. 9

General survey of catch

The distribution of the catch in trap A, June 16 — Sept. 15, 1952, among the different orders of insects is shown in table 15. During the above period a total of more than 116 thousand insect specimens was caught in the trap. It will be seen that the *Diptera* constituted 92.7 per cent of the total, the *Lepidoptera* 4.9 per cent, the *Hemiptera* 1.5 per cent, the *Hymenoptera* 0.5 per cent, the *Coleoptera* 0.2 per cent, and remaining insects 0.2 per cent.

For comparison it should be mentioned that Williams (1939) obtained more than 850 thousand insect specimens in a light trap from the beginning of March 1933 to the end of February 1937. His experiments took place at Rothamsted Experimental Station, north of London, and the trap was in practically continuous use night after night, even during the winter. As in the experiments at Åkarp the *Diptera* comprised the most abundant group, constituting 86.7 per cent of the total. The *Lepidoptera* made up 10.3 per cent of the total, the *Hemiptera* 1.7 per cent, the *Hymenoptera* 0.7 per cent, the *Coleoptera* 0.3 per cent, and the remaining insects 0.2 per cent.

Table 16 shows the total catch of fruit leaf tortricids in the traps, Åkarp 1951—1953. It will be seen that eleven species were captured. Among them

[1] During each of some additional nights (June 1—3, Sept. 30, Oct. 2, 1953), the traps failed to work for about ½—2 hours.

Table 16. Number of specimens of fruit leaf tortricids in the traps, Åkarp 1951—1953. For location of the traps see pp. 218—219.

	Catching place I						Catching place II				Total		
	Trap B 1951		Trap A 1952		Trap A 1953		Trap B 1952		Trap B 1953				
	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂+♀
Spil. ocellana	243	71	180	56	194	23	43	20	60	6	720	176	896
Pand. heparana	95	1	97	1	61	1	9	0	4	0	266	3	269
Cac. podana	94	0	42	0	63	1	21	0	45	1	265	2	267
Acr. naevana	33	1	20	5	55	1	3	1	2	0	113	8	121
Pand. ribeana	24	1	19	0	33	1	14	0	12	2	102	4	106
Acl. variegana	39	0	11	0	12	0	10	0	24	0	96	0	96
Cac. rosana	6	0	11	2	41	1	6	0	24	1	88	4	92
Acl. holmiana	16	2	32	5	10	5	6	2	5	1	69	15	84
Arg. variegana	24	0	14	1	21	1	9	0	6	0	74	2	76
Cac. xylosteana	7	0	6	0	3	0	0	0	0	1	16	1	17
Acl. reticulana	2	0	1	0	6	1	2	0	2	0	13	1	14
Sum	583	76	433	70	499	35	123	23	184	12	1,822	216	2,038

Spil. ocellana was most abundant with a total of 896 specimens, followed by *Pand. heparana* with 269 and *Cac. podana* with 267 specimens. The two least abundant species were *Cac. xylosteana* and *Acl. reticulana* with only 17 and 14 specimens respectively.

The emergence experiments at Åkarp indicate that the sex proportion, e.g. in *Spil. ocellana, Pand. heparana* and *Cac. podana,* is 50:50 or nearly so (cf. table 13 [p. 187]). Despite this males were in excess in the two traps. As can be seen in table 16, a total of 2,038 fruit leaf tortricid specimens were captured; only 216 (or 11 per cent) of these, however, were females. In the separate species the females constituted from zero (*Acl. variegana*) to 20 (*Spil. ocellana*) per cent of the catch.

One of the fruit leaf tortricid species reared at Åkarp, *Cac. lecheana,* was not represented in the catch from the two traps. This fact, combined with the results of the actograph experiments discussed on p. 197, gives strong evidence to show that the males of this species do not normally fly in the night.

Table 17 shows the catch and the sex proportion of twenty-four additional moth species. The figures are for the periods when both traps were in use in 1952—1953 (cf. p. 222). It will be seen that the majority of the species gave in each of the two years more males than females, in trap A as well as in trap B. The noctuid *Scotogramma trifolii* showed considerably more males than females in trap A but an almost equal number of the sexes in trap B. Another noctuid, *Phytometra gamma,* gave more males than females in trap A in 1952 but otherwise almost an equality of the sexes. The geometrid

Table 17. Number of specimens of some moth species in the traps, arranged according to percentage of females. Åkarp 1952—1953. For comparison also figures (last column) showing percentage of females in a light trap at Rothamsted Experimental Station near Harpenden, north of London. All latter figures quoted from Williams (1939).

	1952						1953						1952—1953			1933—1936
	Trap A			Trap B			Trap A			Trap B			Trap A	Trap B	Both traps	Trap at Rothamsted
	♂	♀	% ♀	♂	♀	% ♀	♂	♀	% ♀	♂	♀	% ♀	% ♀	% ♀	% ♀	% ♀
Crambus culmellus L.	46	0	*0*	83	0	*0*	24	0	*0*	182	0	*0*	*0*	*0*	*0*	—
Ancylis lundana F.	109	0	*0*	273	0	*0*	39	1	*3*	126	2	*2*	*1*	*<1*	*1*	—
Malacosoma neustria L.	71	1	*1*	59	1	*2*	7	0	*0*	13	0	*0*	*1*	*1*	*1*	*0*
Spilosoma lubricipedum L.	9	1	*10*	24	1	*4*	20	0	*0*	30	0	*0*	*3*	*2*	*2*	*4*
Palluperina testacea Schiff.	30	0	*0*	78	0	*0*	30	1	*3*	53	4	*7*	*2*	*3*	*3*	*9*
Pyrausta lutealis Hb.	19	0	*0*	18	0	*0*	19	3	*14*	30	2	*6*	*7*	*4*	*5*	—
Mesographe forficalis L.	15	0	*0*	10	0	*0*	25	4	*14*	41	1	*2*	*9*	*2*	*5*	*10*[1]
Triphaena pronuba L.	37	1	*3*	11	3	*21*	19	1	*5*	3	0	*0*	*3*	*18*	*7*	*15*
Agrotis segetum Schiff.	20	1	*5*	9	2	*18*	35	2	*5*	17	1	*6*	*5*	*10*	*7*	—
Polia dissimilis Kn.	4	2	*33*	5	1	*17*	25	1	*4*	18	1	*5*	*9*	*8*	*9*	—
Calothysanis amataria L.	56	5	*8*	36	6	*14*	25	0	*0*	21	2	*9*	*6*	*12*	*9*	*9*[1]
Sideridis conigera Schiff.	28	3	*10*	8	2	*20*	12	1	*8*	7	0	*0*	*9*	*12*	*10*	*24*
Agrotis exclamationis L.	47	3	*6*	21	2	*9*	70	9	*11*	9	3	*25*	*9*	*14*	*10*	*6*
Euxanthis hamana L.	90	13	*13*	143	15	*9*	25	6	*19*	90	9	*9*	*14*	*9*	*11*	*0*[1]
Gortyna leucostigma Hb.	8	1	*11*	4	1	*20*	24	3	*11*	6	1	*14*	*11*	*17*	*13*	—
Endothenia antiquana Hb.	44	15	*25*	73	19	*21*	45	21	*32*	157	23	*13*	*29*	*15*	*20*	—
Rhyacia c-nigrum L.	180	58	*24*	295	115	*28*	601	141	*19*	714	235	*25*	*20*	*26*	*23*	*30*
Amathes lychnidis Schiff.	16	5	*24*	3	3	*50*	94	23	*20*	25	17	*40*	*20*	*42*	*26*	*23*
Rhyacia rubi View.	181	57	*24*	257	157	*38*	137	23	*14*	208	42	*17*	*20*	*30*	*26*	*8*
Plutella maculipennis Curt.	102	61	*37*	364	128	*26*	71	41	*37*	440	141	*24*	*37*	*25*	*28*	*13*[1]
Scotogramma trifolii Hufn.	35	9	*20*	24	26	*52*	37	5	*12*	17	12	*41*	*16*	*48*	*32*	—
Phytometra gamma L.	31	21	*40*	13	14	*52*	8	11	*58*	18	20	*53*	*45*	*52*	*49*	*50*
Cidaria fluctuata L.	33	41	*55*	16	34	*68*	30	33	*52*	20	28	*58*	*54*	*63*	*58*	*58*[1]
Sideridis pallens L.	49	108	*69*	23	45	*66*	40	130	*76*	28	68	*71*	*73*	*69*	*71*	*28*

[1] Applies to 1936 only.

Note: Possibly some additional examples of some of the species among about 70 specimens from trap B, 1952. On examination all latter specimens found to be in a condition unsuitable for identification.

Table 18. Catch of some moth species in trap B expressed as a percentage of corresponding catch in trap A, Åkarp 1952—1953. For absolute figures see tables 16—17.[1]

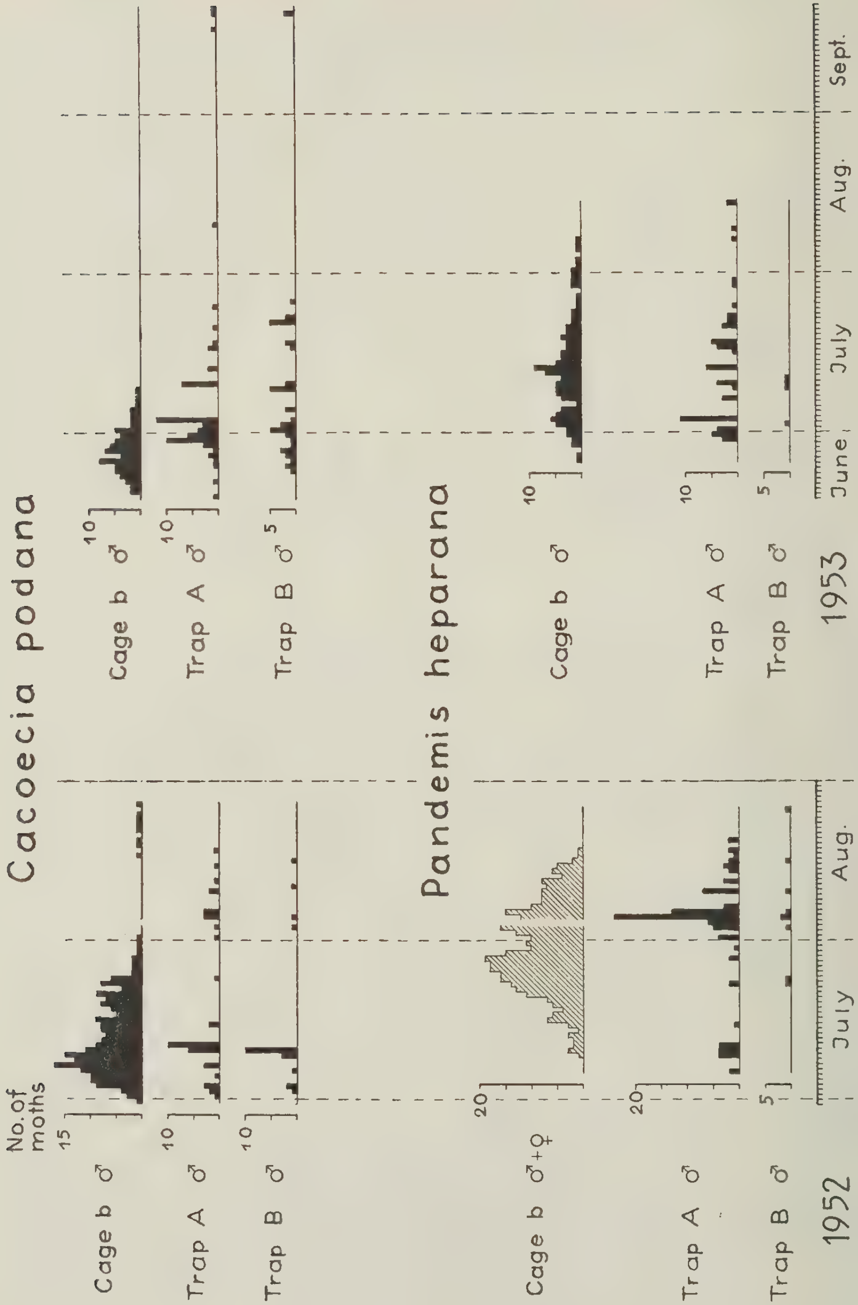
	1952	1953	1952—1953
Fruit leaf tortricid moths			
Acleris variegana	91	200	148
Cacoecia podana	50	72	63
Cacoecia rosana	46	60	56
Pandemis ribeana	74	41	53
Argyroploce variegana	60	27	41
Spilonota ocellana	27	30	28
Acleris holmiana	22	40	27
Pandemis heparana	9	6	8
Acroclita naevana	16	4	7
Other "*Microlepidoptera*"			
Plutella maculipennis	302	519	390
Crambus culmellus	180	758	379
Ancylis lundana	250	320	269
Endothenia antiquana	156	273	218
Euxanthis hamana	153	319	192
Pyrausta lutealis	95	145	122
Mesographe forficalis	67	145	118
"*Macrolepidoptera*"			
Palluperina testacea	260	184	221
Spilosoma lubricipedum	250	150	183
Rhyacia rubi	174	156	167
Rhyacia c-nigrum	172	128	139
Malacosoma neustria	83	186	92
Scotogramma trifolii	114	69	92
Phytometra gamma	52	200	92
Polia dissimilis	100	73	78
Calothysanis amataria	69	92	76
Cidaria fluctuata	68	76	72
Sideridis pallens	43	56	50
Agrotis segetum	52	49	50
Sideridis conigera	32	54	39
Amathes lychnidis	29	36	35
Gortyna leucostigma	56	26	33
Triphaena pronuba	37	15	29
Agrotis exclamationis	46	15	27

1 As in the following pages, the specimens (from trap B, 1952) mentioned in footnote, table 17, are not considered.

Cidaria fluctuata and the noctuid *Sideridis pallens* produced more females than males, in both traps and in both years.

The figures in the last column of table 17 show the percentage of females in some of the species in the trap at Rothamsted (cf. p. 222). As will be seen, they correspond fairly well with the figures from Åkarp. In *Sideridis pallens*, however, the percentage of females was only 28 (total number of males = 149; females = 59) in the Rothamsted trap, i.e. much lower than in the Åkarp traps.

Table 18 shows the catch of some moth species in trap B in relation to the


Cacoecia podana
Pandemis heparana
No. of moths
Cage b ♂
Trap A ♂
Trap B ♂
Cage b ♂+♀
Trap A ♂
Trap B ♂
1952
Cage b ♂
Trap A ♂
Trap B ♂
Cage b ♂
Trap A ♂
Trap B ♂
1953
15
10
20
5
June
July
Aug.
Sept.

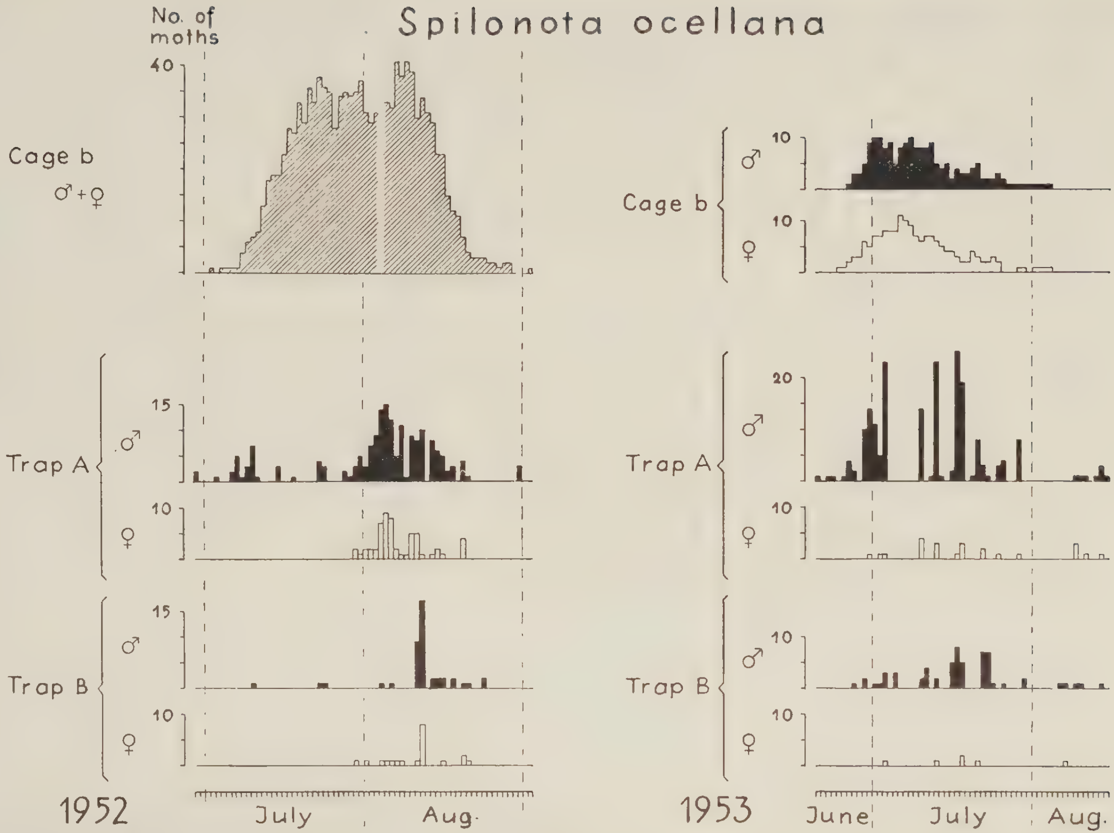


Fig. 39. Abundance of adults (males, or females, or males plus females) in cage *b*, and catch (males, in *Spil. ocellana* also females) in the traps, of some fruit leaf tortricid species, Åkarp 1952–1953.

corresponding catch in trap A. The figures refer to the periods when both traps were operated in 1952—1953. It will be seen that some of the species were in excess in trap A, other species in trap B.

The trees in the apple plantation where trap A was mounted did not receive insecticidal material, either in 1952 or in 1953. In contrast to this, all the trees in the orchard where trap B (in the last-mentioned years) was placed received insecticidal material on several occasions, both in 1952 (DDT and lindane on April 23, parathion on May 12, DDT and lindane on June 13) and in 1953 (DDT and lindane on April 16 and on May 4, DDT on May 29 and on June 29).

Because of the above circumstances it could be expected that a larger number of fruit leaf tortricid specimens would in the two years be captured in trap A than in trap B. As can be seen in table 18, this is also what actually happened. Of the fruit leaf tortricids nine species were in each of the two years more abundant in trap A than in trap B. Only in one species (*Acl. variegana*) was the total catch from the two year period higher in trap B than in trap A.

Regarding two of the fruit leaf tortricid species, *Pand. heparana* and *Acr. naevana,* the catch in 1952--1953 in trap B was less than 10 per cent of the corresponding catch in trap A. Thus, whilst *Pand. heparana* gave a total of 160 specimens and *Acr. naevana* a total of 81 specimens in trap A, the two species produced only 13 and 6 specimens respectively in trap B. In view of the short distance between the two traps (cf. pp. 218—219) the results indicate that the males of the two species are strongly bound to their natural habitats.

Fig. 39 illustrates some of the results of the periodicity studies on the adults of *Cac. podana, Pand. heparana* and *Spil. ocellana* in 1952—1953. It shows the abundance of adults (males, or females, or males plus females) in cage *b*, i. e. in the population experiments discussed on p. 180 ff., moreover the catch (males; in *Spil. ocellana* also females) in the traps. In the case of each of the three species moths were captured in the traps, both in 1952 and in 1953, chiefly during the part of the season when the abundance of adults of the various species was high or fairly high in cage *b*. However, whilst the abundance of adults in the cage generally changed but little from one day to the next, the captures fluctuated considerably. It will be seen in fig. 39 that a night of high catch was often followed by a night of low or zero catch and vice versa. During the two latter thirds of July 1952 only few fruit leaf tortricid specimens were caught, despite the abundance of adults of several of the species, e.g. of *Spil. ocellana*, being high during the same period in cage *b*.

To a large extent the fluctuations in the catch were associated with the influence of the weather upon the activity of the moths. The relation between the catch and the weather is discussed on p. 238 ff.

In *Spil. ocellana* females occurred in the traps mainly in the latter half of the part of the season when males were caught (cf. fig. 39). This applies to each of the three years (1951—1953). Judging from the emergence experiments the peak of emergence in this species happens at most a few days later in the females than in the males (cf. figs. 18—19 [pp. 189 and 191]). The data indicate that the average age of the adults of *Spil. ocellana* when they were captured in the traps, was higher in the females than in the males.

Experiments with marked moths

By capturing and killing insects the light traps caused a reduction of the insect population. To get an idea of the extent of this reduction some experiments with marked moths were made at Åkarp in 1953. In the following some of the results obtained by other workers in studies based on the release of marked moths are first mentioned. Then an account of the experiments at Åkarp is given.

Yetter and Steiner (1932) investigated the dispersal of the oriental fruit moth, *Laspeyresia molesta*. In one of their experiments about 1,200 marked adults were released in a peach district. More than half the number of these moths were recovered (in bait traps), each moth within 15 days after its release. The average distance between the release point and the recovery point was about 140 m. in the males and 160 m. in the females; the maximum distance was about 1.3 km. in the males and 2.0 km. in the females.

Worthley (1932), in a study on the codling moth, *Laspeyresia pomonella*, made a similar experiment. More than 1,400 marked adults, the sexes in almost equal numbers, were released in an apple orchard. About 11 per cent of the males and 12 per cent of the females were recovered (in bait traps). The maximum distance between the release point and the recovery point amounted to about 200 m.

Brower (1931) used in an experiment a total of 1,000 adults of different noctuid species. After being marked the moths were released: 62 specimens close to a light trap, and 938 specimens about 600 m. away from the same trap. Later, a total of 51 of the moths was captured in the trap: 20 (or 32 per cent) of those liberated in the immediate vicinity of the trap and 31 (or 3 per cent) of those liberated farther away. Among the latter 31 moths there were some specimens of *Rhyacia c-nigrum*, a species commonly met with in the traps at Åkarp (cf. table 17 [p. 224]).

Returning now to the experiments at Åkarp, it should first be mentioned that only fruit leaf tortricids were studied. In all, 655 adults were used; 334 specimens in one experiment series (series A), and 321 specimens in another experiment series (series B). The moths were marked with cellulose paint, mainly according to the methods described on pp. 182—183. After the marking they were released in the Substation orchard, always in the daytime before 5 p. m. The release took place at five different points located about 5 m. (one point), about 10 m. (two points) and about 20 m. (two

Table. 19. Summary of experiments with marked moths released in Substation orchard, Åkarp 1953.

	Males							Females						
	No. of release days[1]	No. of moths released about from trap A			Total no. of moths released	No. of moths released and later captured in		No. of release days[1]	No. of moths released about from trap A			Total no. of moths released	No. of moths released and later captured in	
		5 m.	10 m.	20 m.		trap A	trap B		5 m.	10 m.	20 m.		trap A	trap B
Series A														
Acleris reticulana	22	7	14	15	36	0	0	20	9	18	17	44	0	0
Cacoecia podana	8	4	7	7	18	0	0	—	—	—	—	—	—	—
„ *rosana*	11	14	29	28	71	0	1	12	16	32	31	79	0	0
Pandemis heparana	14	5	10	10	25	1	0	6	2	4	5	11	0	0
Spilonota ocellana	14	5	11	10	26	5	2	14	5	9	10	24	1	0
Sum		35	71	70	176	6	3		32	63	63	158	1	0
Series B														
Acleris reticulana	10	17	32	32	81	1	0	6	3	7	6	16	0	0
Cacoecia rosana	3	2	3	3	8	0	0	2	3	7	7	17	0	0
Pandemis heparana	6	2	4	4	10	0	0	8	2	4	5	11	0	0
„ *ribeana*	8	7	14	13	34	4	0		—	—	—	—	—	—
Argyroploce variegana	1	2	2	0	4	2	0	—		—	—	—	—	
Acroclita naevana	8	14	25	22	61	3	1	13	8	18	19	45	0	0
Spilonota ocellana	4	1	2	2	5	1	0	9	2	4	3	9	0	0
Other fruit leaf tortricids	5	4	6	2	12	0	0	5	1	3	4	8	0	0
Sum		49	88	78	215	11	1		19	43	44	106	0	0

[1] No. of release days = no. of days when one or several moths were released.

points) from trap A. One or several moths were liberated on each of 75 days, the first day being June 8 and the last day Sept. 8.

In series A only moths reared in cages were used. Each adult in this series was released within 8 hours after the time when first recorded. Since the cages were examined but once a day and since some of the adults emerging in them were probably not discovered until the second day or still later after their emergence, no exact figures can be given showing the number of moths released on the emergence day etc. On the basis of the observations made in the experiments discussed on p. 182 ff., however, it can be calculated that more than 80 per cent of the moths included in series A were released within 32 hours after their emergence from the pupa, more than 95 per cent within 56 hours.

In series B both adults from rearing experiments and adults captured in the field (in an orchard located about 1½ km. from the Substation orchard) were used. At least a large proportion of the moths included in this series were released several days after their emergence.

Some of the moths which were marked and released were recovered, either in trap A or in trap B. A summary of the catch is given in table 19.

To begin with the males in series A, it will be seen in the table that a total of 176 moths, distributed among five species, was released. In *Acl. reticulana* not one of 36 moths, and in *Cac. podana* not one of 18 moths, came into the traps. In *Cac. rosana* only one of 71 moths, and in *Pand. heparana* only one of 25 moths, was recovered. In *Spil. ocellana*, however, seven of 26 moths were recovered (never more than one specimen during one and the same night).

Many males were released also in series B, altogether 215 specimens. In *Acl. reticulana* only one of 81 moths was recovered, in *Acr. naevana* four of 61 moths, and in *Pand. ribeana* four of 34 moths. Of the remaining 39 males (different species) three specimens were recovered.

Turning to the females in series A, it can be seen in table 19 that a total of 158 specimens was released, only 11 of *Pand. heparana*, but 24 of *Spil. ocellana*, 44 of *Acl. reticulana*, and 79 of *Cac. rosana*. Of all these females only one specimen (*Spil. ocellana*) was recovered.

Moreover, a fairly large number of females was used in series B, a total of 106 specimens being distributed among several species. None of these females was recovered.

During the period June 29—July 3, 1953, several fruit leaf tortricid species, e.g. *Pand. heparana*, *Acr. naevana* and *Spil. ocellana*, were unusually abundant in trap A (cf. fig. 51 [p. 255]). In view of this it is worth noting that a rather large number of moths was marked and released late in June and early in July, 1953. The number of males released from June 25 to and including July 3 was as follows:

	June 25—27	June 28—30	July 1—3	Total
Cac. rosana	29	21	10	60
Pand. heparana	4	4	5	13
Acr. naevana	0	29	14	43
Spil. ocellana	5	6	6	17
Other species	7	2	1	10
All species	45	62	36	143

Thus, the total number of males released in the nine days was 143. Ten of them were recovered: one specimen (*Spil. ocellana*) before June 29; seven specimens (one of *Pand. heparana*, two of *Acr. naevana*, four of *Spil. ocellana*) during the period June 29—July 3; two specimens (*Acr. naevana*, *Spil. ocellana*), finally, after July 3.

As can be seen in table 19, twenty-two of the moths which had been marked and released were recovered. Eighteen of them came into trap A and four into trap B. Of the former moths six had been released about 5 m., seven about 10 m. and five about 20 m. from trap A; of the four moths entering trap B two (*Acr. naevana*, *Spil. ocellana*) had been released about 35 m., one (*Cac. rosana*) about 45 m. and one (*Spil. ocellana*) about 60 m. from trap B.

Table 20 shows the time interval between the release and the recovery (the catching in trap A or in trap B) of the above twenty-two moths. It will be seen that most of the moths were recovered within 6 days after their release; some of them, however, considerably later. The single female (*Spil. ocellana*; cf. above) came into trap A during the 13th night after its release.

Considering the results of the experiments it may be suspected that both traps together caught 20—30 per cent or even more of the males of *Spil.*

Table 20. Time interval between release and recovery (catching in trap A or in trap B) of marked adults, Åkarp 1953.

	Number of moths captured during													
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th	13th	23rd
	night after release													
Acl. reticulana	—	—	—	1	—	—	—	—	—	—	—	—	—	—
Cac. rosana	—	—	—	—	—	—	—	—	1					
Pand. heparana	—	—	—	—	1	—	—	—	—	—	—	—	—	—
„ *ribeana*	1	1	1	1	—	—	—	—	—	—	—	—	—	—
Arg. variegana	—	—	—	—	—	2	—	—	—	—	—	—	—	—
Acr. naevana	—	2	—	—	—	—	—	1	—	—	—	1	—	—
Spil. ocellana	1	2	1	1	1	—	—	—	—	—	—	1	1	1
Sum	2	5	2	3	2	2	—	1	1	—	—	2	1	1

ocellana emerging in the Substation orchard during 1953. For several other species, e. g. *Acl. reticulana* and *Cac. rosana,* however, the experiments indicate that less than 5 per cent of the males emerging in the same area and during the same year were captured.

As already mentioned, females of fruit leaf tortricids were less abundant in the traps than males (cf. p. 223). The experiments with marked moths indicate that not even females occurring close to the traps were attracted to any great extent by the electric light.

Note: The marked moths caught in the traps are not included in the summaries given in table 16, table 18, and fig. 39. Nor are they, unless otherwise stated, considered in the following pages.

Night distribution of catch

Oddly enough only few workers seem to have paid any great attention to the problem concerning the times of night at which moths are attracted to artificial light. Some of the most interesting data published are as follows:

Ainslie (1917), in a study made in Tennessee, USA, found that both sexes of *Crambus teterrellus* were frequently attracted to some lighted windows. Most of the females appeared in the early part of the night, most of the males in the middle part.

Kaburaki and Kamito (1929) used a light trap in Japan. For some nights they determined the hourly distribution of *Chilo simplex.* They discovered that the moth to a large degree came to the trap before midnight. In the females the peak occurred one or two hours after sunset, in the males two or three hours later.

Husain, Khan, and Ram (1934), in light trap experiments in Punjab, studied the abundance of *Platyedra gossypiella.* Sometimes maximum flight happened in the early part of the night, sometimes in the middle or in the late part. Observations were also made indicating that the males appeared, in the main, somewhat later in the night than the females.

Williams (1935, 1939) has contributed the most important papers on the night distribution of moth activity as indicated by light trap captures. In the light trap used by him there were eight killing jars on a turntable. Assuming that the night starts half an hour after sunset and ends half an hour before sunrise each jar was kept exposed for approximately one eighth of the night, four jars before and four after midnight. The trap was operated according to this method almost continuously night after night for four years (at Rothamsted Experimental Station, north of London; cf. p. 222).

Many of the moth species studied by Williams showed an individuality in night distribution. Some of them came to the trap mainly in the early part of the night, other species mainly in the middle part, and some mainly in the late part. In one species at least, the noctuid *Parastichtis secalis,* the

females showed a clear tendency to appear earlier in the night than the males.

Regarding the time of night when fruit leaf tortricids are attracted to artificial light, published data are very meagre. Collins and Nixon (1930), in light trap studies in Monroe County, New York, found that *Spil. ocellana* was generally captured in greatest numbers before 11:30 p. m. (local time). Williams gives figures illustrating the night distribution of *Arg. variegana* (in 1933—1934) and *Acl. variegana* (in 1933—1936) in the trap exposed at Rothamsted (cf. above). The former species showed a fairly smooth distribution over most of the night; the latter species, on the other hand, came chiefly late in the night.

Turning now to the experiments at Åkarp, it has already been explained that trap A was often provided with *several* killing jars which stood on a turntable and which were automatically changed at hourly intervals (cf. p. 214). The jar-changing mechanism was used from June 30 to and including Oct. 14 in 1952, also from June 8 to and including Oct. 9 in 1953. During a total of eight nights (Aug. 5, Sept. 22, 23 and 28 in 1952; June 16 and 23, Oct. 2 and 6 in 1953), however, the trap or the turntable did not work satisfactorily. These eight nights are not included in the following discussion.

Strictly speaking, the interval between two successive changes varied between about 55 and 67 minutes (average during each night about 59—62 minutes). The error caused by the variations is of no great importance and no regard is paid to it below. It is assumed that the turntable always changed at the intended time, i.e. at 9 p. m., 10 p. m. etc.

In many cases insect specimens, e.g. fruit leaf tortricids, settled on the outside of the trap, many of them finally entering the catching device, yet some of them probably not until they had stayed on the outside for hours. However, judging from observations made in connection with the light trap operations, the greater part of the moths and the other insect specimens entering the catching device were stupefied (or killed) and fell down into the killing jar less than 10 minutes after they had arrived at the trap.

It can be mentioned in this connection that a watch was kept on the trap throughout the night of July 17, 1953. An attempt was made to determine the times at which specimens of *Spil. ocellana* came to the trap. Roughly estimated, 35 specimens[1] of this species were in the night in question attracted to the trap, about *5* specimens between 10 and 11 p. m., about *21* specimens between 11 and 12 p. m., and about *9* specimens between 0 and 1 a. m. During the same night a total of 27 specimens[1] of *Spil. ocellana* was captured in the trap: *3* of them in the jar exposed from 10 to 11 p. m., *17* in the jar exposed from 11 to 12 p. m., and *7* in the jar exposed from 0 to 1 a. m.

[1] Marked moths included; cf. p. 233.

The dusk period is in the following text considered to start at sunset and to end at the time when the sun is lying six degrees below the horizon. *The dawn period* is considered to be the corresponding period ending at sunrise. *The dark period* is considered to be the remaining part of the night.

As far as the females of most of the fruit leaf tortricid species are concerned, the investigations at Åkarp give only few data illustrating the daily rhythm or the night distribution of the flight activity. For this reason mainly the males are taken into account below.

Before continuing the discussion of the light trap experiments it should be pointed out that the flight activity in the field of the males of *Pand. heparana, Acr. naevana, Cac. rosana* and *Acl. holmiana* largely takes place in the dusk period. On the basis of the actograph experiments mentioned on p. 197 it may be suspected that the same applies also to the males of several other fruit leaf tortricid species, e.g. to the males of *Pand. ribeana.*

The investigations at Åkarp give only little information about the behaviour of the moths in the field at dawn. It can be mentioned that in the garden where trap A was mounted (in 1952—1953) several males of *Acl. holmiana* but otherwise no fruit leaf tortricids were seen flying in the dawn period of the night of July 17, 1953.

Figs. 40—41 show the distribution in successive five day periods of the males of some fruit leaf tortricid species among the different jars in the trap. As can be seen, at most only occasional specimens were attracted to the electric light during the dusk period and during the dawn period. Because of the relatively strong daylight prevailing during these periods, this was only to be expected.

Moreover, it will be seen that the males of *Pand. heparana* and *Acr. naevana* showed a tendency to appear in the early part of the dark period. The peak in the males of *Spil. ocellana* and *Cac. podana* happened in the middle part of the night, in the latter species somewhat later than in the former. The males of *Acl. holmiana*, despite the fact that they frequently fly in the dusk period (cf. above), were not caught in the early part of the dark period but mainly in the late part of the night. Also *Acl. variegana* showed (as in the light trap experiments carried out by Williams; cf. p. 234) a distinct maximum late in the night.

Because of the successive alteration in the length of the night it is only natural that the distribution among the different jars changed, as the season advanced. In *Pand. heparana* and *Acr. naevana* males occurred mainly in the periods 10—11 and 11—12 p. m. during June and July but mostly in the periods 9—10 and 10—11 p. m. during August. In *Spil. ocellana* the males appeared mainly in the periods 11—12 p. m. and 0—1 a. m. during June and July but in fairly great numbers in each of the hours from 10 p. m. to 2 a. m. later in summer. In *Acl. holmiana* males generally came into the trap in the periods 1—2 and 2—3 a. m. during July but mostly in the periods 2—3 and 3—4 a. m. during August.

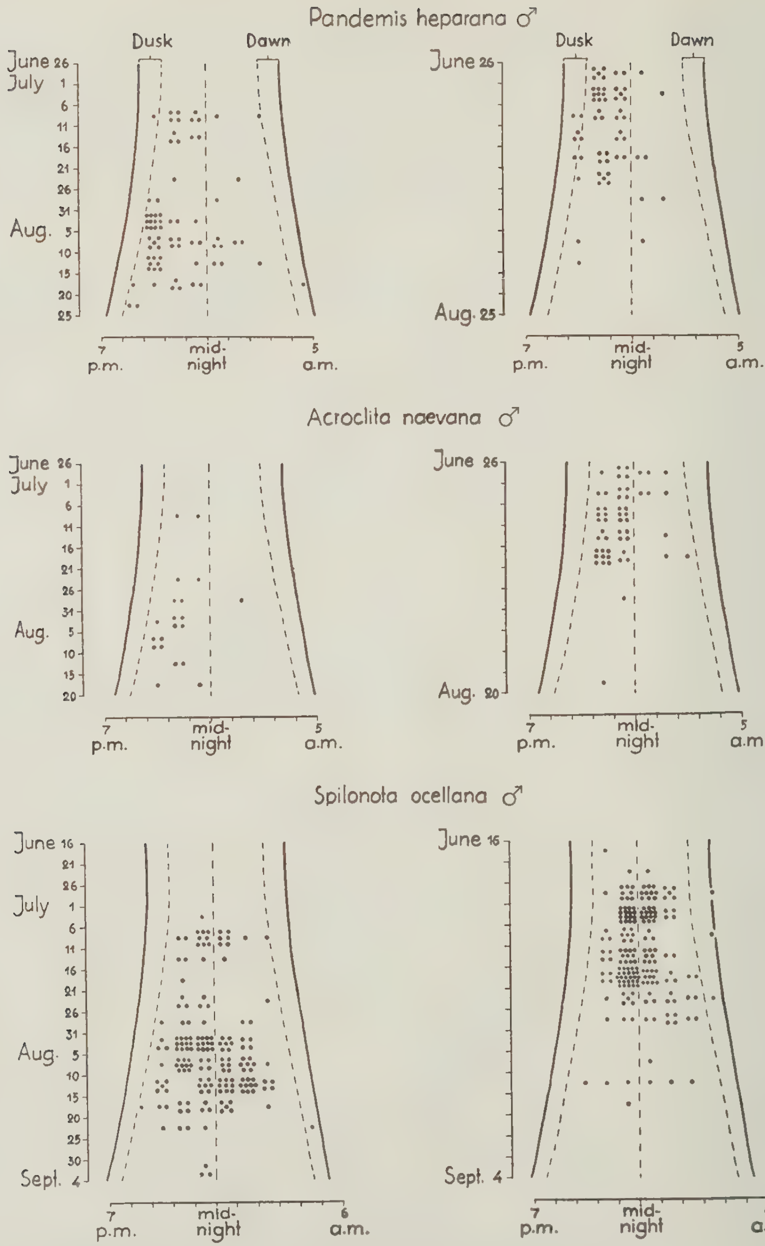


Fig. 40. Night distribution of the males of some fruit leaf tortricid species in trap A. — Left = Åkarp 1952. Right = Åkarp 1953. — Each dot = one specimen.

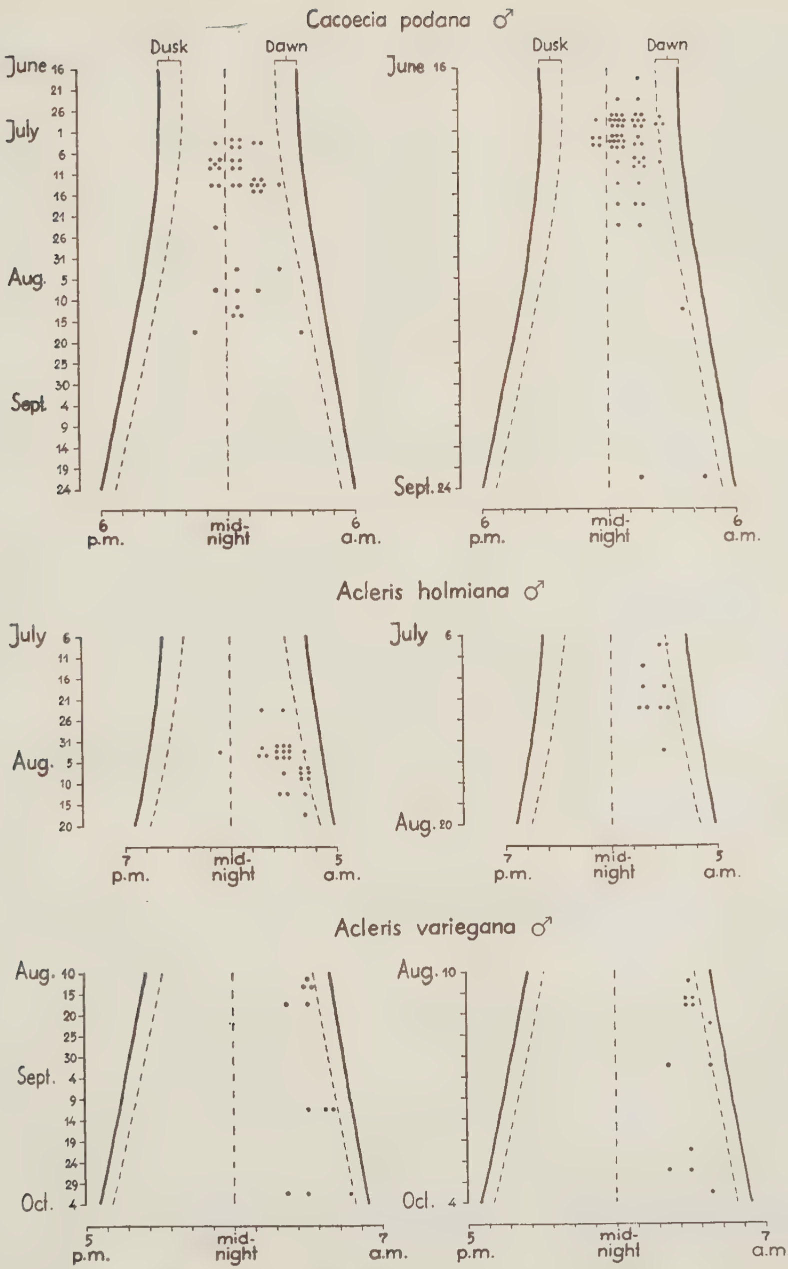


Fig. 41. Night distribution of the males of some fruit leaf tortricid species in trap A. — Left = Åkarp 1952. Right = Åkarp 1953. — Each dot = one specimen.

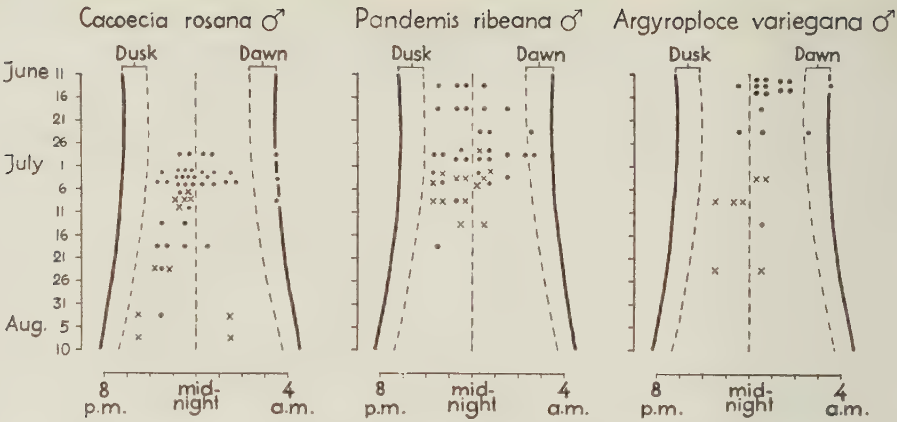


Fig. 42. Night distribution of the males of some fruit leaf tortricid species in trap A. — Crosses = Åkarp 1952. — Dots = Åkarp 1953. — Each cross, as each dot, = one specimen.

Fig. 42 illustrates the distribution of the males of some additional fruit leaf tortricid species. As can be seen, males of *Pand. ribeana* and *Cac. rosana* mainly entered the trap early or fairly early in the dark period, usually less than 180 minutes after the end of the dusk period. Males of *Arg. variegana* were captured in various parts of the dark period.

In *Spil. ocellana* the night distribution of the females showed no significant difference from that of the males (cf. fig. 47 [p. 247]). In *Acl. holmiana* (in trap A 1952—1953) 6 females but only 1 male were obtained before midnight, 3 females but 36 males after midnight.

Relation of catch to physical environment

Introductory remarks

The problem of the relation in the field between the activity of insects flying in the night and the physical environment is complicated and for various reasons difficult to solve.

There are a great number of references to the subject in literature (cf. Uvarov 1931). Many of them, however, are founded on general impressions and therefore of limited value. In other cases unsatisfactory information is given about the location of the meteorological apparatus used, in relation to the place(s) where the insect activity was studied. Often the catch from traps, e.g. from light traps operated during the whole night, is compared only with the weather conditions registered once or a few times during the day. Separate analyses of males and females seem to be rare, and the successive changes in the adult population are frequently paid little, if any atten-

tion. In several papers only the relation of captures or samples of large insect groups (regardless of the distribution among different species) to physical environment is discussed.

Nevertheless, there are valuable contributions, e.g. Williams' paper (1940) on the effect of the weather upon insect activity as indicated by a light trap. A paper by Larsen (1943), on the importance of master factors for the activity of adult noctuid moths, is penetrating from several points of view. Among other interesting accounts can be noticed the detailed study by Stirrett (1938) on the adult moths of *Pyrausta nubilalis*.

With regard to fruit leaf tortricid species published data are very few. Some of them (Collins and Nixon 1930, de Jong [1954]) are discussed on p. 258.

At Åkarp an attempt was made to clarify some points regarding the relationship of the catch in the light traps (trap A and trap B; cf. p. 213 ff.) to the physical environment. An account of the chief results of the studies is given in the following pages.

In addition to fruit leaf tortricid moths great attention was paid to the catch of the *Psychodidae* (*Diptera*). As is well known, adult psychodids can be easily and rapidly distinguished from all other insects. Psychodids came frequently into the traps throughout the period between dusk and dawn. They were sorted out and counted both in 1951 and in 1952 (but not in 1953). It was found that the catch of the *Psychodidae* could be used as an indicator of the suitability of the weather for the catching of many other insects, e.g. *Pand. heparana* and *Spil. ocellana*.

The late Mr Sven Berdén determined a total of 253 psychodid specimens captured in trap B on June 24, 1951; also a total of 163 psychodid specimens captured in trap A on July 1—2, 1952. The distribution among species and sexes, of the former as well as of the latter specimens, is summarized in table 21.

As can be seen, the *Psychodidae* gave, in trap B on June 24, 1951, a total of 277 specimens, distributed among at least four species; the most abundant species was *Psychoda severini* with more than 200 examples.

With reference to the *Psychodidae* in trap A on July 1, 1952, a total of 190 specimens representing more than six species was obtained; once again *P. severini* was the most abundant species.

In the same trap, on July 2, 1952, the *Psychodidae* produced a total of 45 specimens; there was a total of five species, the most abundant being *P. severini* with 31 examples.

The examinations indicate that in some psychodid species mainly females came into the traps. In *P. severini*, for example, there are, among the identified specimens discussed in table 21, 346 females but only 3 males. It can be mentioned that this species, according to Tonnoir (1922, 1940), largely reproduces by parthenogenesis.

Several of the species listed in table 21, viz. *P. severini*, *P. trinodulosa*, *P. brevicornis*, *P. crassipenis*, and *P. setigera*, do not seem to have been recorded earlier from Sweden. *P. lativentris* was described by Berdén in Opuscula Entomologica, 1952.

Table 21. Catch of the Psychodidae in one night in 1951 (Åkarp, trap B), and in two nights in 1952 (Åkarp, trap A).

	No. of specimens in night of		
	June 24 1951	July 1 1952	July 2 1952
Identified specimens			
Psychoda severini Tonn. ♂	2	1	0
♀	226	89	31
„ *phalaenoides* L. ♀	13	16	11
„ *trinodulosa* Tonn. ♂	0	2	0
♀	11	7	0
„ *albipennis* Zett. ♀	0	1	1
„ *brevicornis* Tonn. ♂	0	0	1
♀	0	1	0
„ *lativentris* Berd. ♀	1	0	0
„ *crassipenis* Tonn. ♂	0	1	0
„ *setigera* Tonn. ♂	0	0	1
Unidentified specimens	24	72	0
Sum	277	190	45

Unfortunately no figures of night-wind direction or night-cloud are available from Åkarp. At the Meteorological Station of Malmö Airport (Bulltofta, located about 8 m. above sea-level, about 7 km. S.S.W. of the Plant Protection Substation at Åkarp), however, observations are made at 30 or 60 minute intervals, even during the night (to 1 a.m.). These observations have been kindly placed at my disposal and have been used in the analysis of the catch.

Not until the summer of 1956 were regular observations of wind direction and cloud made at Åkarp. The observations took place in the Substation garden, three times a day (at 7 a.m., 1 p.m. and 7 p.m.). In figs. 43—44 the data from July 1956 are compared with the corresponding data from Malmö (Bulltofta; cf. above).

Fig. 43 shows the wind direction. In a few cases there was a large difference between the registrations at the two places. On the whole, however, a close correlation exists.

Fig. 44 shows the cloud conditions. In this figure, as in the following text, the sky is considered to have been *clear* when (according to the estimations made) not more than 3 tenths of it were overcast, *intermediate* when 4—6 tenths and *cloudy* when 7—10 tenths were overcast. It will be seen in fig. 44 that there was, on the whole, a good correspondence between the conditions at Åkarp and Malmö.

Wind velocity

In the light trap experiments carried out by Williams (1940) the number of insect specimens entering the trap showed a tendency to decrease with

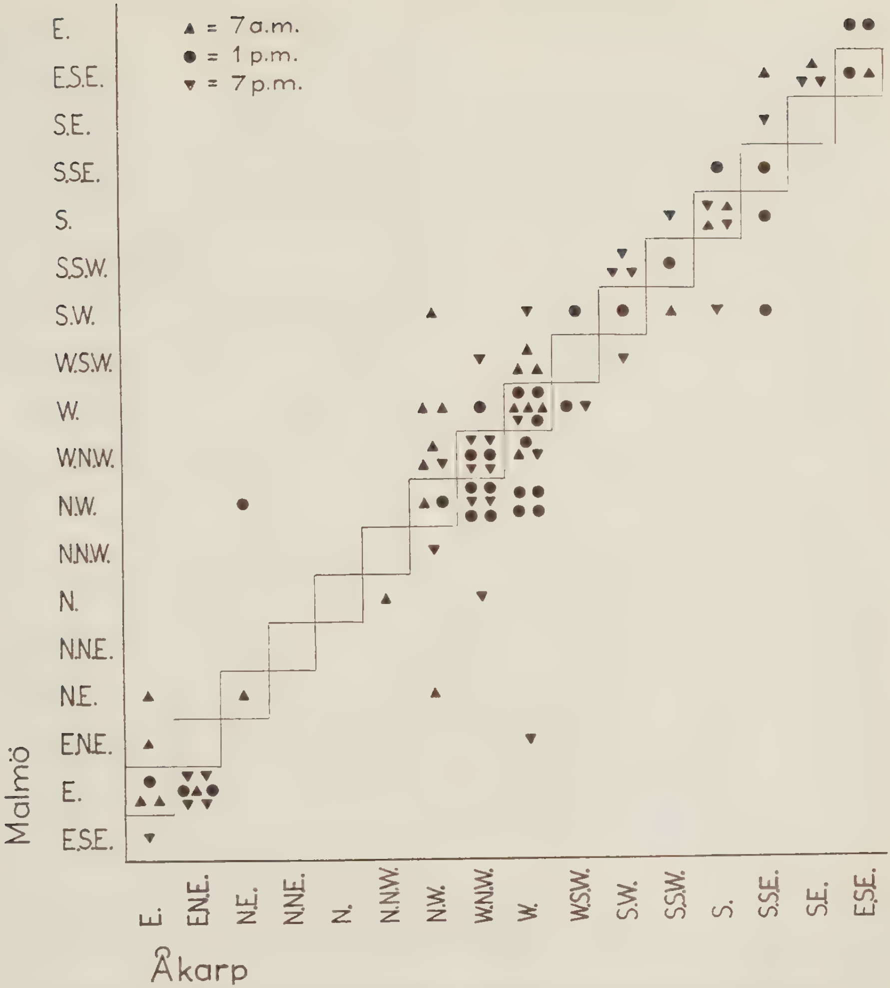


Fig. 43. Comparison of wind direction at Åkarp and Malmö in July 1956.

increasing wind velocity. The observations made by Larsen (1943) indicate that windy weather frequently causes adult moths of the *Noctuidae* to feed in sheltered positions. Marchal (1912) states that windy weather checks the flight activity of the two vine tortricid moths, *Clysia ambiguella* and *Polychrosis botrana*. According to Borden (1931), even a slight breeze keeps down the flight activity of the codling moth, *Laspeyresia pomonella*.

Eyer (1937), on the contrary, in codling moth studies in 1935 and 1937, did not succeed in finding any significant correlation of the wind velocity to the captures of the moth in a series of traps. Unfortunately he gives little information about the meteorological apparatus used, only stating that

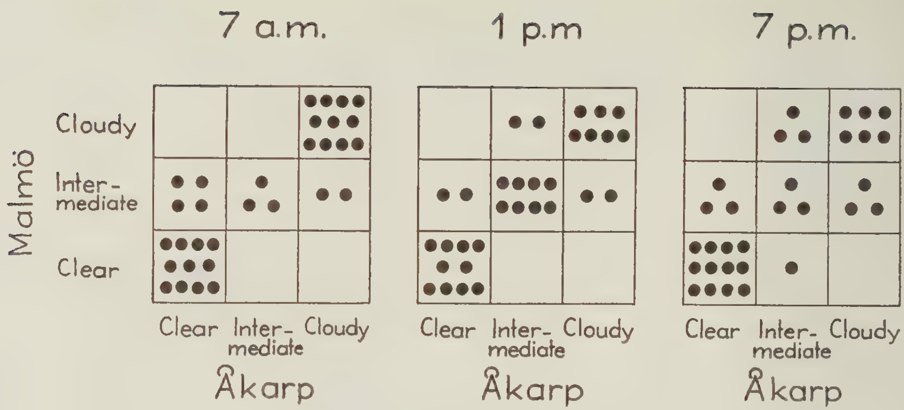


Fig. 44. Comparison of cloud at Åkarp and Malmö in July 1956.

"all weather factors were recorded by standard instruments for one hour at sunset time and again at sunrise". There are no data in his paper showing the location of the meteorological apparatus in relation to the traps.

Stirrett (1938), in his abundance studies on the corn borer, *Pyrausta nubilalis,* found no correlation between the wind velocity and the number of adult moths observed during different evenings and nights on hourly examinations in plots of corn. In this case, however, the figures indicating the moth abundance include not only the moths seen in flight but also those found resting on the plants. Judging from the observations made by Huber *et al.* (1928) windy weather often causes adult moths of *Pyrausta nubilalis* to seek shelter on plants, e.g. on corn plants.

At Åkarp the wind velocity was not recorded in 1951; exact figures are absent also for the nights of 1953; satisfactory data, however, are available for a large part of the summer of 1952. Unless otherwise stated, the following discussion is based on the studies made during this latter year.

All the figures for the wind velocity presented in figs. 46—48 and 50 refer to the conditions in the central part of the Substation orchard, about 5 m. from the ground. The figures are founded on the number of electrical contacts produced by a cup anemometer (R. Fuess). The location of the anemometer in relation to trap A can be seen in fig. 32:A (p. 213).

With the aid of a portable anemometer (R. Fuess) the cup anemometer was tested in air currents of different strength (in a tunnel equipped with a fan-blower). Practically speaking, there was a proportionality between the number of contacts per time unit and the strength of the air current. However, with weak currents, up to a strength of about 1½ m. per sec., there was no straight-line relationship. The number of contacts per 60 minutes at 1 m. per sec., for example, was less than half the number of the contacts per 60

minutes at 2 m. per sec. At ½ m. per sec. no or only single contacts were produced.

From the tests it might be concluded that the cup anemometer gave no exact figures for the lowest wind velocities. This fact, however, is of secondary importance in the present connection and is not taken into account in the following. When the number of contacts per 60 minutes constituted one, two or three fourths of the number of contacts per 60 minutes at 2 m. per sec. the average wind velocity is considered to have been ½, 1 and 1½ m. per sec. respectively.

Each of the wind velocity figures in figs. 46—48 and 50 shows the average wind velocity during a certain hour[1] and night. In the case of each night *the minimum wind velocity* is considered to be the average wind velocity during the hour showing the lowest average wind velocity; *the maximum wind velocity* is considered to be the average figure for the hour showing the highest average velocity. Every hour characterized by an average wind velocity of 0—0.4 m. per sec. is considered to be a *calm* hour, 0.5—1.4 m. per sec. a *slightly windy* hour, 1.5—2.9 m. per sec. a *moderately windy* hour, 3 m. per sec. or more a "*strong-windy*" hour.

It can be mentioned that trap A had a fairly wind-exposed position, particularly when the wind was E.—S.—W. By using the portable anemometer already referred to, some wind measurements were taken in 1953 at different levels above the ground in the Substation orchard. All measurements were made less than 2 m. from the platform on which trap A was situated, always on its windward side. The results are given in fig. 45. As can be seen, the wind velocity at the 4 m. level, i.e. at the same level as the light bulb of the trap (cf. p. 219), was somewhat lower than at the 5 m. level but distinctly higher than e. g. at the 3 m. level.

Fig. 46 shows that there is a close correlation between the catch of psychodid specimens (trap A, July—August 1952) and the wind velocity. The strong concentration of the catch to calm hours is strikingly proved. Generally, no or only few specimens entered the trap during moderately windy hours. With few exceptions no specimens were recorded during "strong-windy" hours. It is particularly worth mentioning that there is a clear relationship between the catch and the wind also for nights which were in part calm, in part windy (cf. e.g. the nights of July 15, 18, and Aug. 11).

In the course of July—August 1952[2] a total of 1,175 psychodid specimens came into trap A during slightly or moderately windy hours, i.e. during hours showing an average wind velocity of 0.5—2.9 per sec. (cf. above). Many of these hours, however, showed longer or shorter calm periods. Less than

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[1] By hours the consecutive 24ths of the day (0—1 a. m., 1—2 a. m. etc.) are meant. The first hour of the night is considered to be the hour in which the sun sets, the last hour of the night the hour in which the sun rises.

[2] The records for the nights of July 3, 12, Aug. 5, 23, 24 and 28 are incomplete. These nights are therefore not considered (cf. fig. 46).

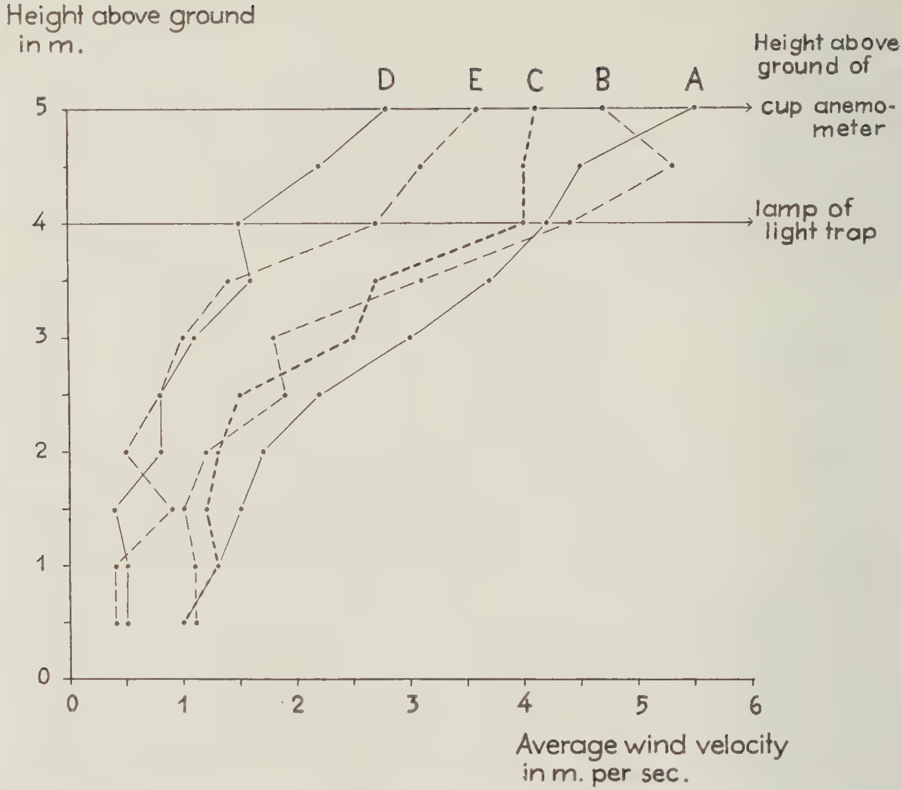


Fig. 45. Vertical distribution of wind velocity in central part of Substation orchard, Åkarp. — A—C = July 16, 1953 (wind direction S.W.). D—E = Aug. 7, 1953 (wind direction N.W.).

Note: In each of the five series (A—E) ten 3 minute measurements with a portable anemometer were carried out (one at 5 m. level, then successively one at 4½ m. level, one at 4 m. level etc.). All the measurements, in each series, were made within a period of < 50 minutes.

2 per cent of the above 1,175 specimens entered the trap in hours during which the wind velocity was never lower than 1 m. per sec.; more than 80 per cent of them, on the other hand, in hours each of which showed a wind velocity of less than 0.5 m. per sec. during more than 3 minutes. In some of the slightly windy hours the wind velocity was less than 0.5 per sec. during a period of more than 20 minutes, e.g. in the hour 1—2 a. m. on the night of July 11, and in the hour 9—10 p. m. on Aug. 1. During the former hour 217 psychodid specimens came into trap A, during the latter hour 153 specimens (cf. fig. 46).

Fig. 47 illustrates for July—August 1952 the relation of the catch of males of *Pand. heparana* and of the two sexes of *Spil. ocellana* in trap A to

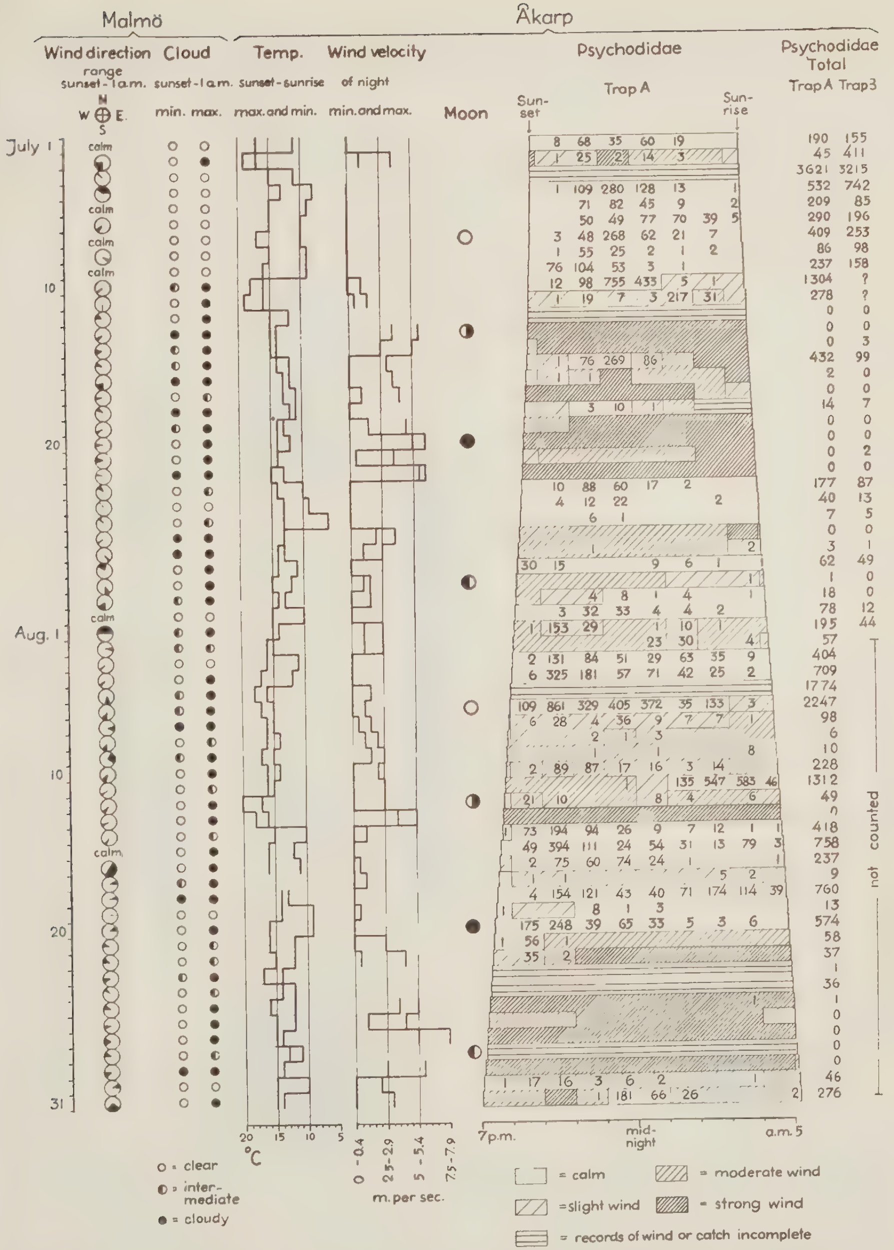
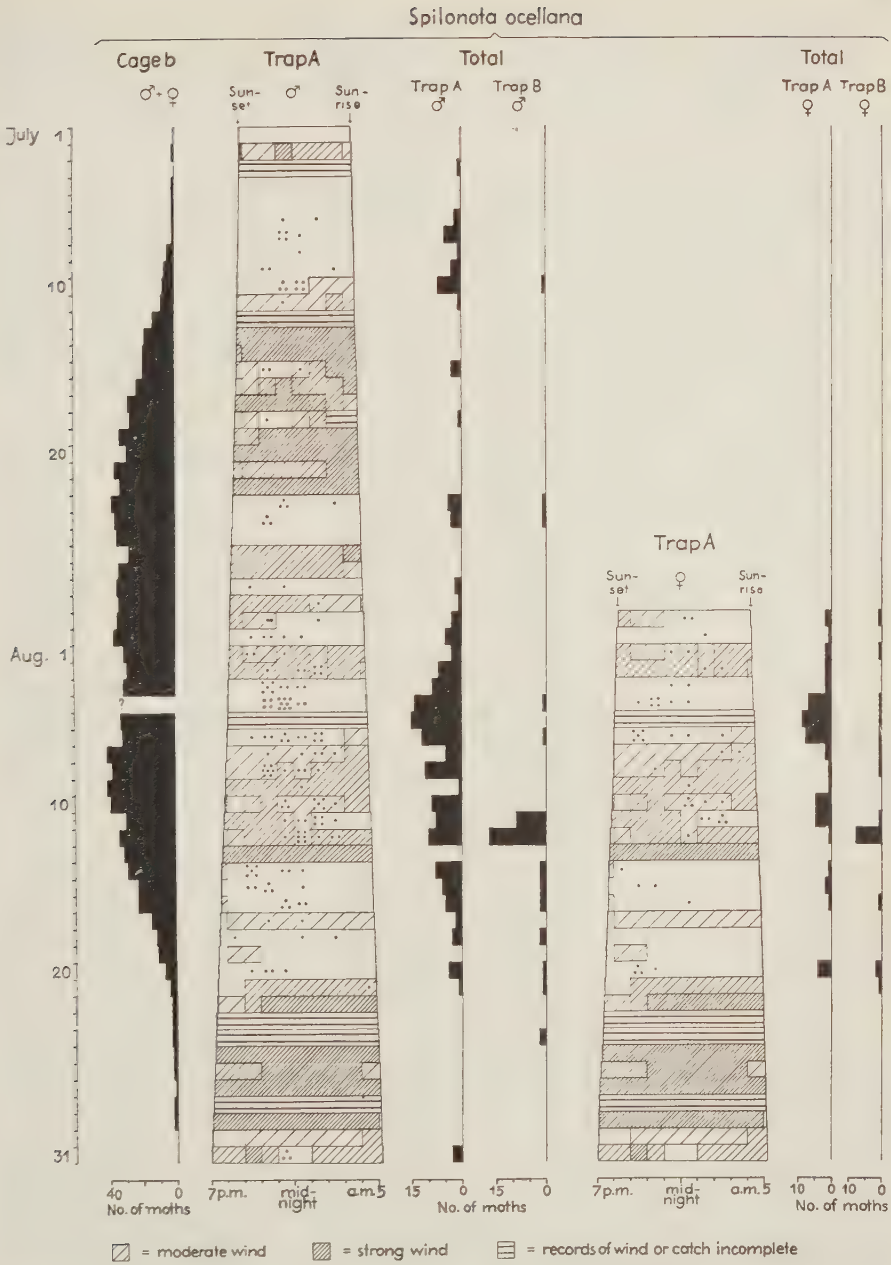


Fig. 46. Relation of catch (no. of specimens) of the *Psychodidae* in the two traps at Åkarp to wind velocity and some other factors, July—August 1952. *Wind dir.* and *cloud* = observations at Malmö Airport (cf. p. 240). *Temp.* and *wind vel.* = thermograph (cf. p. 260) and cup anemometer (cf. p. 242) in Substation garden, Åkarp.

Fig. 47. Relation of catch of males of *Pandemis heparana* and of both sexes of velocity, temperature, moon, and adult abundance of the two species in cage *b* *vel.* = same records as in fig. 46.



Spilonota ocellana in trap A (each dot = one specimen) and in trap B to wind (population experiments; cf. p. 180 ff.), Åkarp, July—August 1952. *Temp.* and *wind*

the adult abundance of the two species in cage *b* (i.e. in the population experiments discussed on p. 180 ff.), as well as to the wind velocity and some other factors. The data on the abundance in cage *b* have been included to give a rough idea of the successive alteration in the adult population in the field.

There exists, as seen in fig 47, a clear correlation between the catch of the above-mentioned moths and the wind velocity. Throughout the part of the season when adults of the two species occurred in the field the catch showed a very marked concentration to calm or only slightly windy hours.

Probably, the adults of all the fruit leaf tortricid species caught in the traps are sensitive to windy weather conditions. Regarding several of the species evidence for this is given by the data in fig. 50 (and also by those in fig. 51; cf. below).

It can be mentioned that in trap A in July—August 1952 a total of 417 fruit leaf tortricid specimens (*Pand. heparana* plus *Spil. ocellana* 283 specimens, remaining species 134 specimens) was obtained.[1] Of them 280 specimens (or 67 per cent of the total) came into the trap in calm hours; 98 specimens (or 24 per cent) in slightly windy hours; 39 specimens (or 9 per cent) in moderately windy hours; no specimens at all in "strong-windy" hours.

In various other insect species the catch in the trap was also closely associated with calm or slightly windy hours. This applies even to many moth species with robust body constitution, e.g. to the noctuids *Rhyacia rubi* (cf. fig. 48) and *Rhyacia c-nigrum.* From time to time, however, specimens of the two latter species (as well as of some other insect species) entered the trap in "strong-windy" hours.

During 1952—1953 some comparative wind measurements were carried out near trap A (Substation orchard, about 4 m. above ground, windward side of trap, 2—3 m. from light bulb) and near trap B (orchard east of Substation orchard [cf. p. 217 ff.], about 1 m. above ground, windward side of trap, 2—3 m. from light bulb). The portable anemometer mentioned on p. 242 was used. The results are given in table 22. When the wind was N.—E.—S. the two traps seem to have been almost equally exposed to the wind. During the periods when the wind was S.W.—W., however, trap B was less exposed than trap A.

It could be expected that the catch in trap B would show a considerably less marked correlation than the catch in trap A to the wind velocity recorded by the cup anemometer in the Substation orchard. In several insect species this was also found to be the case, e. g. in the noctuid *Rhyacia rubi* and in the tortricid *Ancylis lundana.* With regard to the *Psychodidae* and the fruit

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1 Catch in the nights of July 3 and Aug. 5 not included (cf. foot-note 2, p. 243).

Table 22. Wind velocity in m. per sec. close to the two traps as indicated by 3 minute measurements made with a portable anemometer.

Date	Wind direction	Close to trap A		Close to trap B	
		Measurement begun	Average wind velocity	Measurement begun	Average wind velocity
Aug. 23 1952	W.	9:20 a. m.	2·6	9:25 a. m.	1·2
	,,	9:30	2·5	9:35	1·3
	,,	9:45	2·4	9:50	1·2
Aug. 26 1952	W.	2:10 p. m.	2·8	2:20 p. m.	0·9
	,,	2:30	3·0	2:40	0·8
	,,	2:45	2·8	2:50	1·1
Aug. 28 1952	W.	10:40 a. m.	5·4	10:45 a. m.	2·2
	,,	10:50	5·2	10:55	2·3
	,,	11:05	5·4	11:10	2·2
Aug. 22 1952	S.W.	9:15 a. m.	3·1	9:20 a. m.	1·4
	,,	9:25	3·1	9:30	2·1
	,,	9:35	2·7	9:40	1·6
Sept. 2 1952	S.W.	10:00 a. m.	3·4	10:05 a. m.	1·8
	,,	10:15	3·2	10:20	2·3
	,,	10:25	3·5	10:30	1·9
Sept. 27 1952	S.W.	1:50 p. m.	3·1	1:55 p. m.	3·7
	,,	2:00	3·8	2:05	2·3
	,,	2:10	3·4	2:15	2·5
Aug. 25 1952	S.W.	11:00 a. m.	3·7	11:05 a. m.	2·4
	,,	11:10	3·6	11:15	2·0
	S.	11:30	3·6	11:35	3·6
Oct. 14 1953	E.	0:50 p. m.	2·5	0:55 p. m.	2·0
	,,	1:00	1·1	1:10	2·2
	,,	1:15	2·1	1:20	1·6
Sept. 9 1952	N.E.	10:45 a. m.	1·1	10:50 a. m	2·2
	,,	10:55	1·8	11:00	2·0
	,,	11:05	1·7	11:10	1·6
Sept. 15 1952	N.	11:05 a. m.	1·1	11:10 a. m.	1·1
	,,	11:20	0·9	11:25	0·8
	,,	11:30	0·5	11:35	1·2

leaf tortricids, however, the available data do not show such a clear difference between the two traps (cf. figs. 46—47).

Fig. 48 illustrates for the period Aug. 1—Sept. 5, 1952, the relation of the catch of *Rhyacia rubi* and *Ancylis lundana* in the two traps to the wind velocity about 5 m. from the ground in the Substation orchard.

As can be seen, the nights during the period Aug. 14—20 were calm or only slightly windy. *Rhyacia rubi* gave during these nights in the two traps a total of 206 specimens, 89 (or *43 per cent*) of them in trap B; *Ancylis lundana* gave a total of 215 specimens, 148 (or *69 per cent*) of them in trap B.

In the period Aug. 21—29 at least five nights showed six or more "strong-windy" hours each. The prevailing wind direction, judging from the observations

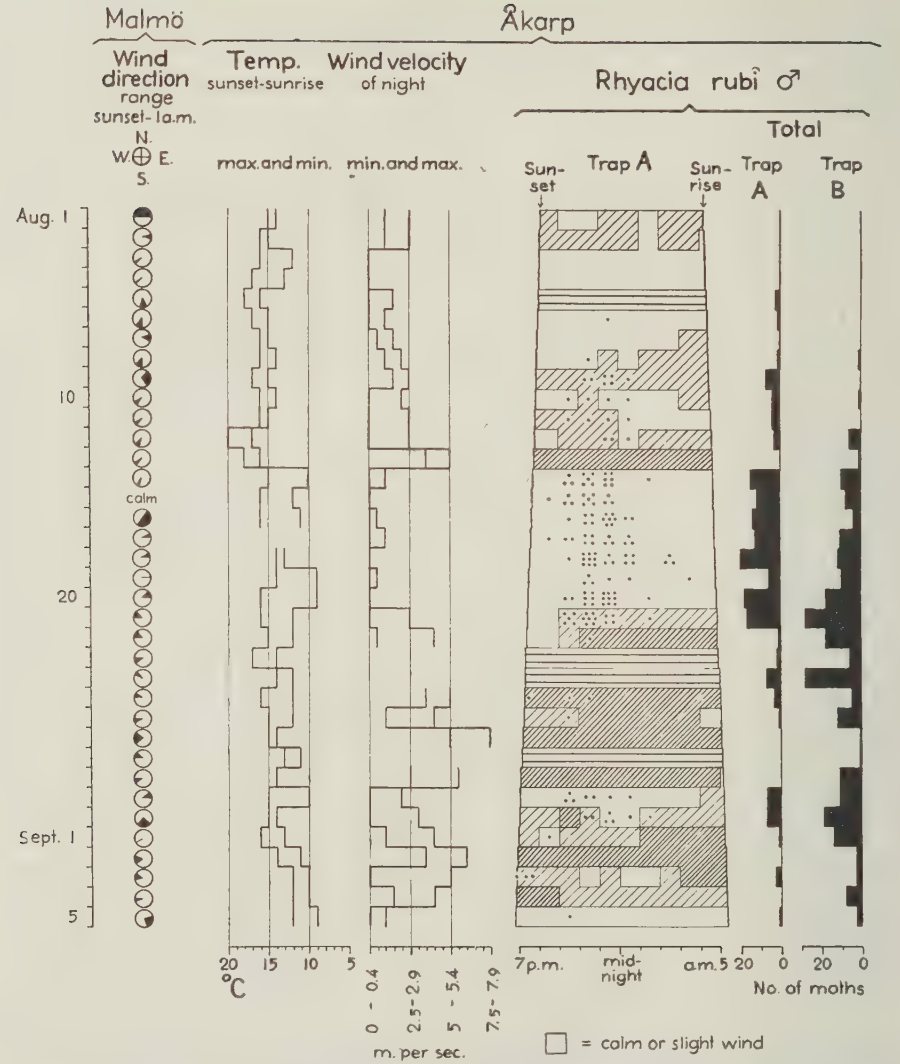
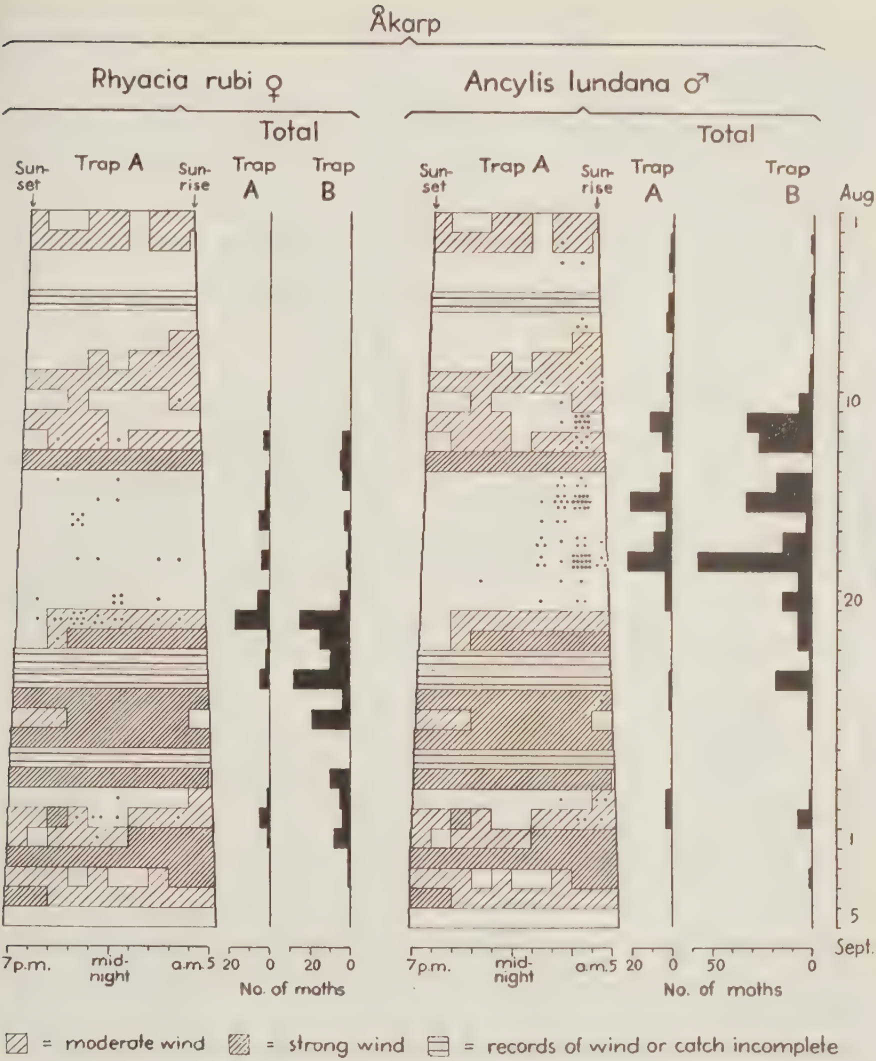


Fig. 48. Relation of catch of *Rhyacia rubi* and *Ancylis lundana* in trap A (each Aug. 1—Sept. 5, 1952. *Wind dir.*=observations at Malmö Airport (cf. p. 240). in Substation garden, Åkarp.

Note: During the above period no females of *Ancylis lundana* were captured in the

at Malmö Airport, in each of the five nights was westerly. *Rhyacia rubi* produced during the five nights a total of 101 specimens, 95 (or *94 per cent*) of them in trap B; *Ancylis lundana* produced a total of 12 specimens, 11 (or *92 per cent*) of them in trap B.

Through the courtesy of the Meteorological Station at Bulltofta, Malmö, figures



dot=one specimen) and in trap B to wind velocity and some other factors, *Temp.* and *wind vel.*=thermograph (cf. p. 260) and cup anemometer (cf. p. 242)

traps.

of the wind velocity during the period sunset — 1 a. m. (one or two observations per hour) at Malmö Airport are available. (For location of the Airport see p. 240.)

Fig. 49 shows a comparison of the calculated average of the wind velocity at Malmö and Åkarp during 57 four hour periods (9 p. m. 1 a. m.) in July August 1952. The figures from Malmö are founded on the above-mentioned observations, those from Åkarp on the wind registrations in the Substation orchard (cf. p. 242).

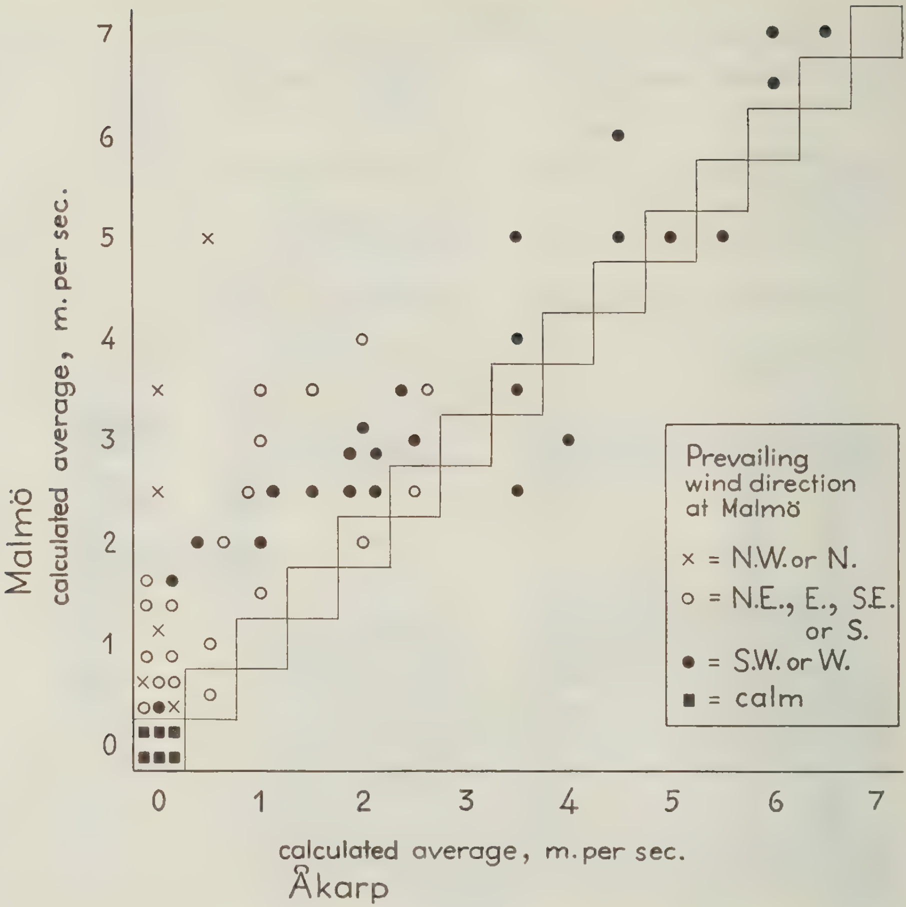


Fig. 49. Comparison of wind velocity at Åkarp (Substation orchard) and Malmö (Airport) in 57 four hour periods (9 p. m.—1 a. m.), July—August 1952.

Note: For the remaining five periods, 9 p.m.—1 a. m., July—August 1952, no complete data are available.

It will be seen that there is a fairly good resemblance between the two sets of figures. When the wind (at Bulltofta, probably also at Åkarp) was N.W. or N., however, the wind velocity was in several cases considerably higher at the Airport than in the Substation orchard.

The data in fig. 51 are for the period June 10—July 31, 1953. They illustrate the relation of the catch of the *Lepidoptera* and of some fruit leaf tortricid species in trap A to the wind velocity (Malmö, sunset — 1 a. m., cf. above) and some other factors. As will be seen, the figures indicate that there was also in 1953 a close correlation between the catch and the wind velocity.

In the summer of 1957 additional studies on the effect of the weather upon

insect activity as indicated by light trap captures were made. Some data from the light trap experiments in this latter year are given below.

Trap A was situated in the garden of the Plant Protection Substation, Åkarp, in the same place and on the same platform (light bulb about 4 m. above ground) as in 1952—1953 (cf. p. 218). However, since most of the trees in the Substation orchard had been cut in 1954—1956, the trap occupied in 1957 a more wind-exposed position than in the 1952—1953 experiments.

Trap B was situated on the ground (light bulb about 1 m. above ground) in a sheltered position in an apple plantation at Alnarp, about 600 m. W.N.W. of trap A.

The photographs reproduced in fig. 52 were taken in August 1957. The upper picture shows trap A in the Substation garden, the lower picture trap B in the orchard at Alnarp.

The wind velocity was recorded in the Substation garden by means of a cup anemometer. The anemometer was situated about 9 m. above ground, about 35 m. S. of trap A. It was not identical with but of the same type (R. Fuess) as that operated in 1952. The lowest wind velocities (up to a strength of about 1 or 1½ m. per sec.) the anemometer did not record exactly. As in the case of the cup anemometer used in 1952 this fact is disregarded. A number of contacts per 60 minutes corresponding to one, two or three fourths of the number per 60 minutes at 2 m. per sec. is considered to indicate an average wind velocity of ½, 1, and 1½ m. per sec. respectively.

The following figures give an idea of the relation between the wind conditions in the place where the cup anemometer was situated and of the wind conditions close to the two traps.

During the period 9:40—10:30 a. m., June 28, 1957, the wind direction was W.S.W.—W.; during the period 10:15—11:15 a. m., Aug. 9, 1957, E.—S.E. The cup anemometer showed an average wind velocity of *6½* m. per sec. in the former period, of about *8½* m. per sec. in the latter period. As indicated by measurements made with portable anemometers the average wind velocity during the same two periods close to trap A (4 m. above ground, windward side of trap, 2—3 m. from light bulb) was about *4½* (June 28) and *3½* (Aug. 9) m. per sec., close to trap B (1 m. above ground, windward side of trap, 2—3 m. from light bulb) about *1* (June 28) and 2 (Aug. 9) m. per sec.

The traps were only operated from 11 p. m. to 1 a. m. This two hour period, in the continued discussion, is called *the midnight period.*

Fig. 53 illustrates for the period July 19—Aug. 5, 1957, the relation between the catch of some insect groups or species in the two traps and some weather factors, e.g. the wind velocity (cup anemometer about 9 m. above ground, Substation garden). By *Tortricidae* the moth species included in *Tortricinae, Phaloniinae,* and *Epibleminae* are meant.

As can be seen, the cup anemometer showed in each of nine of the eighteen midnight periods an average wind velocity of 2 m. per sec. or less, in each of the remaining nine midnight periods an average wind velocity of 3½ m. per sec. or more. The former nine periods are called *the "light-wind" midnight periods* below; the other nine periods are called *the "heavy-wind" midnight periods.*

In the "heavy-wind" midnight periods a higher number of insect specimens was, as expected, caught in trap B (sheltered trap) than in trap A (wind-exposed trap). This is exemplified by the following figures (all of which refer to the period July 19—Aug. 5).

Beginning with the *Psychodidae,* a total of 1,418 specimens was caught in trap

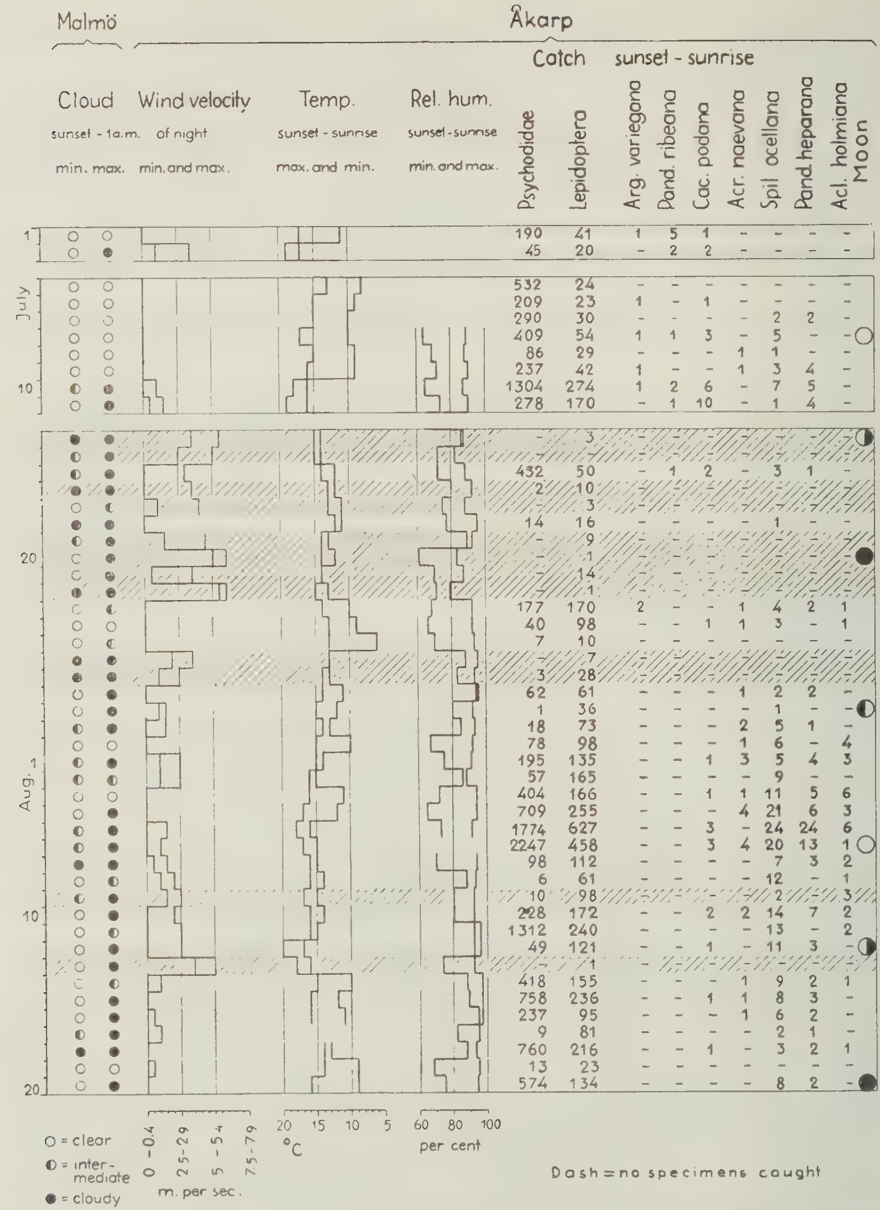


Fig. 50. Relation of catch (no. of specimens) of the *Psychodidae*, the *Lepidoptera*, and of some fruit leaf tortricid species, in trap A to various factors, July 1—Aug. 20, 1952. *Cloud*=observations at Malmö Airport (cf. p. 240), *Wind vel.*, *temp.*, and *rel. hum.* =cup anemometer (cf. p. 242), thermograph (cf. p. 260), and hygrograph (cf. p. 266) in Substation garden, Åkarp.

Note: Diagonal lines indicate the different nights in which the cup anemometer showed, in each of the hours between 10 p. m. and 2 a. m., an average wind velocity of 1.5 m. per sec. or more.

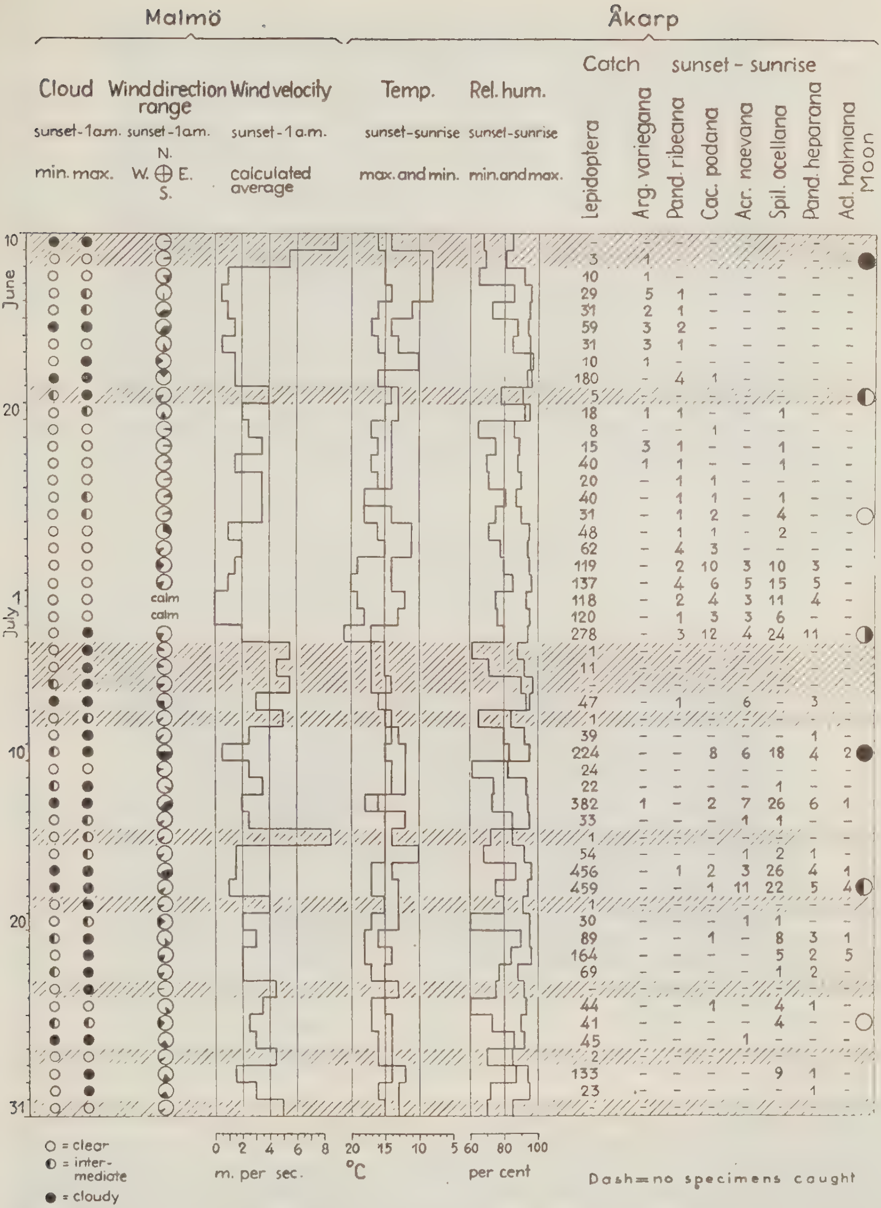


Fig. 51. Relation of catch (no. of specimens) of the *Lepidoptera*, and of some fruit leaf tortricid species, in trap A to various factors, June 10—July 31, 1953. *Cloud, wind dir.,* and *wind vel.*=observations at Malmö Airport (cf. pp. 240 and 252). *Temp.* and *rel. hum.*=thermograph (cf. p. 260) and hygrograph (cf. p. 266) in Substation garden, Åkarp.

Note: Diagonal lines indicate the different nights showing in period sunset — 1 a. m. at Malmö Airport a calculated average wind velocity of 4 m. per sec. or more.

Fig. 52. From the light trap experiments in 1957. Above. Trap A (Substation garden, Åkarp) seen from the northeast. Below. Trap B (orchard at Alnarp) seen from the west.

A, a total of 607 specimens in trap B. Zero of the former but 23 (or 4 per cent) of the latter specimens were recorded in the "heavy-wind" midnight periods.

The *Tortricidae* produced a total of 177 specimens in trap A, a total of 192 specimens in trap B. Only 8 (or 5 per cent) of the former but 73 (or 38 per cent) of the latter specimens entered the respective traps in the "heavy-wind" midnight periods.

With regard to the *Noctuidae* a total of 273 specimens was recorded in trap A, a total of 52 specimens in trap B. In all, 33 (or 12 per cent) of the former specimens, 25 (or 48 per cent) of the latter specimens were captured in the "heavy-wind" midnight periods.

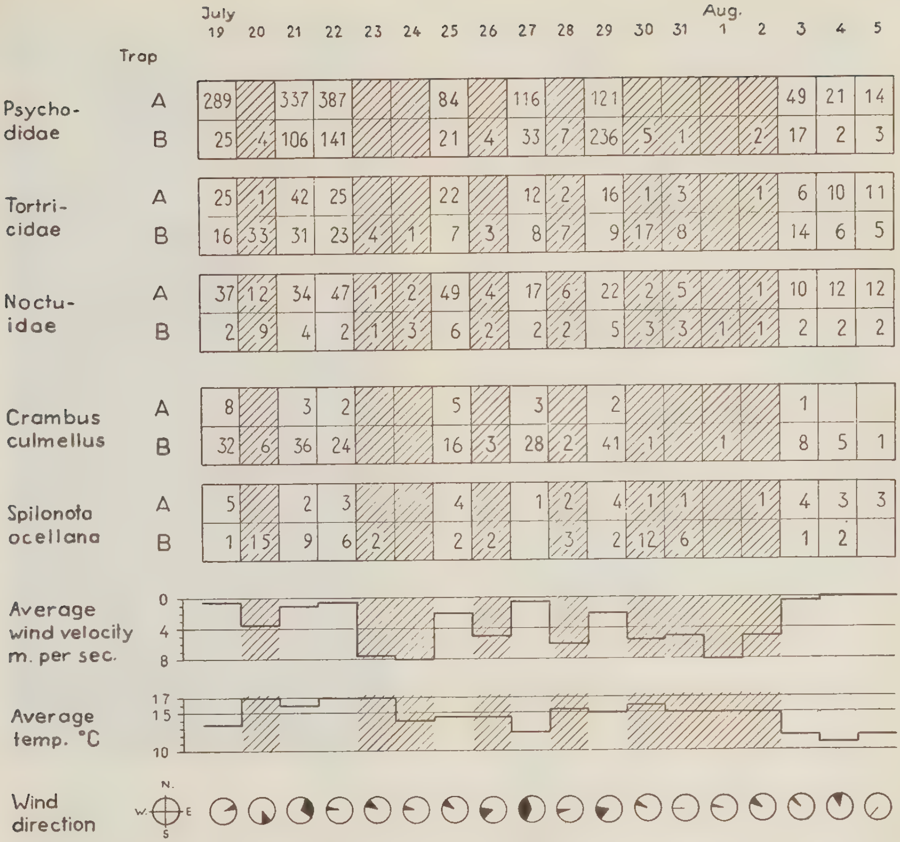


Fig. 53. Relation of catch (no. of specimens) of some insect groups etc. in trap A (Substation garden, Åkarp) and in trap B (orchard at Alnarp) to wind velocity (cup anemometer about 9 m. above ground, Substation garden), temperature (bourdon thermograph, about 2 m. above ground, in a screen of type shown in fig. 55, Substation garden) and wind direction (observations at Malmö Airport; cf. p. 240), July 19—Aug. 5, 1957. All figures referring to period 11 p. m.—1 a. m.

Note: Diagonal lines indicate the different two hour periods (11 p. m.—1 a. m.) when the cup anemometer showed an average wind velocity of 3½ m. per sec. or more.

Among the various moth species *Crambus culmellus* gave a total of 24 specimens in trap A, a total of 204 specimens in trap B. All the former specimens were caught in the "light-wind" midnight periods. Thirteen (or 6 per cent) of the specimens entering trap B were recorded in the "heavy-wind" midnight periods.

The most abundant fruit leaf tortricid species was *Spil. ocellana*. In trap A this species produced a total of 34 specimens, in trap B a total of 63 specimens. Only 5 (or 15 per cent) of the former specimens but 40 (or 63 per cent) of the latter specimens were captured in the "heavy-wind" midnight periods.

Temperature

Hervey and Palm (1935) used light traps in a study on the corn borer, *Pyrausta nubilalis*. Their figures indicate a close positive correlation between the activity of the moth and the temperature during night. Parrott and Collins (1934) exposed light traps in an investigation on the codling moth, *Laspeyresia pomonella*. The figures give also in this case strong evidence to show that activity increased with increasing night temperature.

Recently de Jong ([1954]) operated light traps in a study on a fruit leaf tortricid, *Adoxophyes orana*. The moth came to the light even during nights showing an initial temperature ("at the beginning of the evening twilight") of only 12 °C.

Collins and Nixon (1930) used more than a hundred light traps in an investigation on *Spil. ocellana*. They compared the captures from eleven nights in June—July 1929 with the temperature at 9 p. m. (local time). Although they conclude that the activity of the moth was very definitely inhibited when the temperature fell as low as 60 °F (= 15.6 °C), this is not proved by their figures. In a table they give the following data for the first five of the above eleven nights:

Date	°F at 9 p.m.	No. of traps counted	No. of moths (*Spil. ocellana*)
June 18	75	105	2
19	72½	100	59
28	60	104	1,036
July 1	70	104	1,023
6	68½	104	2,053

As can be seen, the 9 p. m. temperature is stated to have been 60 °F on June 28. During the night of this date, according to the figures published, more than a thousand *Spilonota* specimens were captured.

Turning to the investigations at Åkarp, it should first be mentioned that the temperature was recorded by means of thermistors in the Substation orchard on Aug. 16—17, 1955. The weather was sunny, both on Aug. 16 and on Aug. 17. Three of the thermistors discussed on p. 181 were used. They were mounted above each other, one of them 1 m. from the ground, one 2½ m. and one 4 m. from the ground. The location of the thermistors in relation to trap A (which had the same position as in the experiments in 1952—1953) as well as to the vegetation appears from fig. 54:A. Each thermistor was kept shielded against the sun by a piece of white cardboard.

Fig. 54:B gives a summary of the results. The data clearly indicate that the radiation, not only in the daytime but also in the night, was considerable. As expected, the night temperature during the test period averaged at the

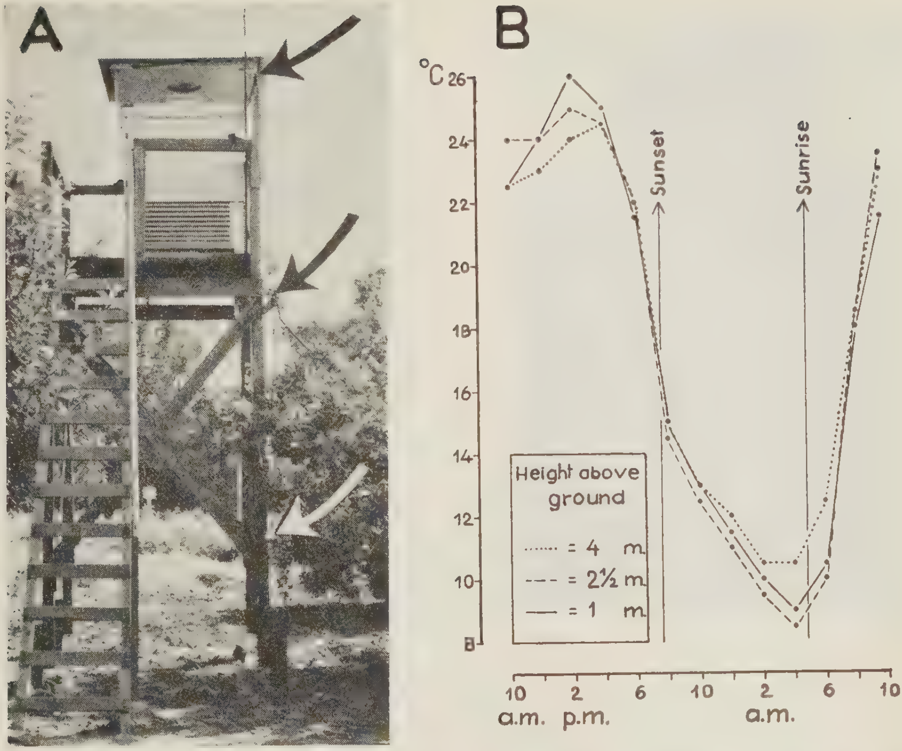


Fig. 54. Studies on temperature based on thermistor measurements, Substation orchard, Åkarp, Aug. 16—17, 1955. A = points (indicated by arrows) where thermistors were situated. B = results of measurements.

4 m. point, i.e. at a point level with the light bulb of the trap, a somewhat higher figure than at the two other points. The night temperature at the 2½ m. point differed but little from that at the 1 m. point.

In connection with the light trap experiments the thermometer screen shown in fig. 55 was used. It was situated (in 1951—1955) in the Substation garden, about 30 m. northwest of the trap in the Substation orchard (cf. fig. 38, p. 221). The screen contained a mercury thermometer, also a bourdon thermograph (Richard frères). Both instruments were located about 1½ m. above the ground.

The figures in the following tabular survey refer to the period when the above-mentioned thermistor measurements (Aug. 16—17, 1955) were made. They show the maximum, the minimum, and the 9 a. m. temperature, both in the screen (mercury thermometer) and at different levels in the Substation orchard (thermistors).

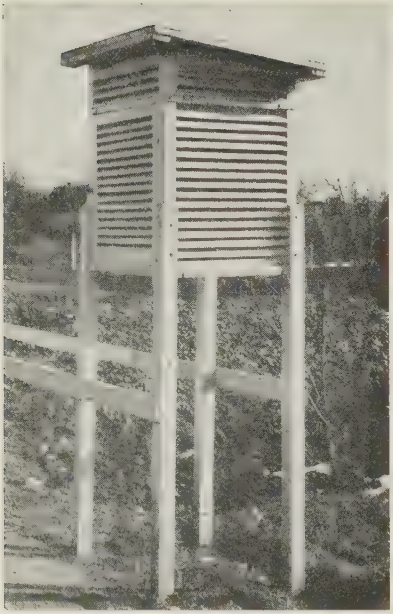


Fig. 55. The thermometer screen.

	Screen	Open air		
	1½ m.	1 m.	2½ m.	4 m.
Max.	26 °C	26½	25	24½
Min.	9½	9	8½	10
9 a. m.	21	20½	21	21

It will be seen that there are only small differences between the figures from the screen and the figures from the open air.

The thermograph in the screen worked with great accuracy, both in 1952 and in 1953. Fig. 56 is based on all readings made in the screen at 9 a. m. in June—August 1952—1953. As will be seen, a close correlation exists between the temperature as shown by the mercury thermometer and the temperature as shown by the thermograph.

The temperature figures presented in the graphic representation or in the following text are according to the above thermograph, unless otherwise stated. The figures for individual hours show the average temperature of the various periods.

In June—August 1952—1953, the night temperature (from sunset to sunrise) ranged from 6 ° to 21 °C. By *low, fairly low, moderate, fairly high,* and *high* temperature the temperatures 6—8.9 °, 9—10.9 °, 11—12.9 °, 13—14.9 ° and 15—21 ° are meant. Night-temperatures below 9 ° or above 17 ° occurred only occasionally.

Fig. 57 shows that psychodid specimens were frequently abundant both at high, fairly high, and moderate temperatures. Provided the temperature

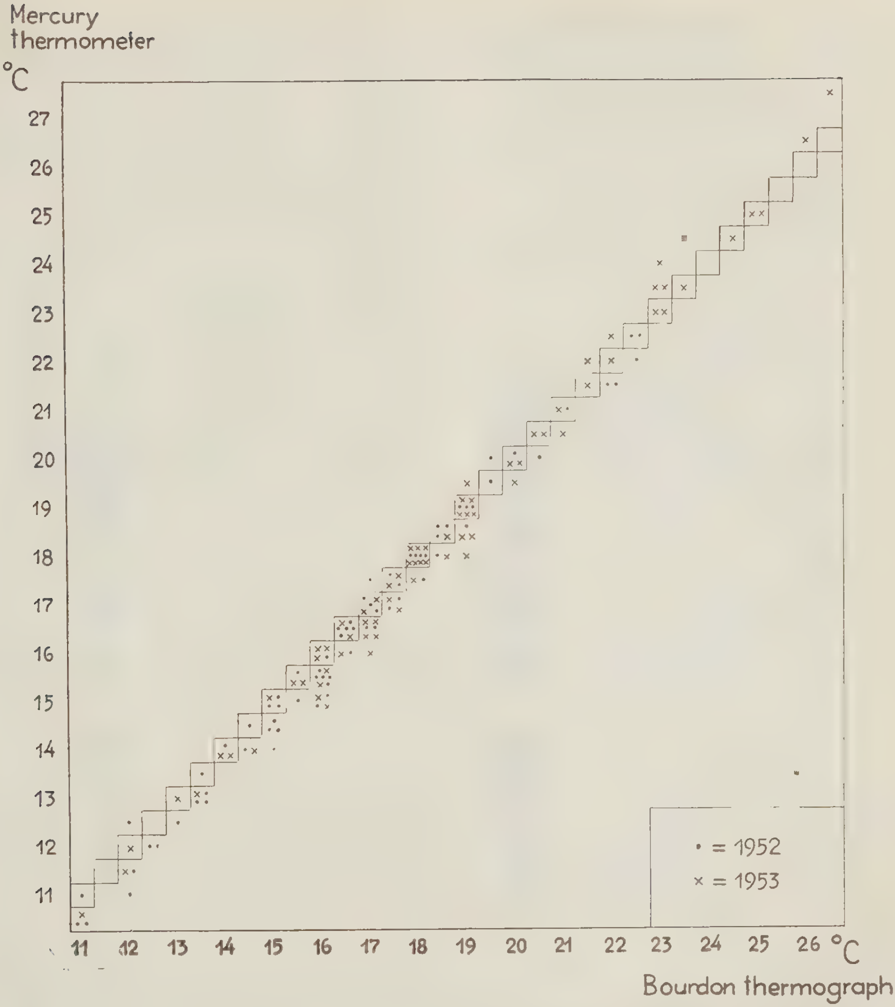


Fig. 56. Temperature in thermometer screen. Comparison of figures shown by mercury thermometer and figures shown by bourdon thermograph. For further explanation see text.

was fairly low or low, however, the psychodid catch was generally low or zero, even in calm weather.

Fig. 58 shows the catch of *Pand. heparana* and *Spil. ocellana* in trap A and the temperature in most of the calm night-hours in July—August 1952. Moreover, fig. 58 contains figures indicating the abundance of adult moths of the two species in cage *b*, i.e. in the population experiments accounted for on p. 180 ff.

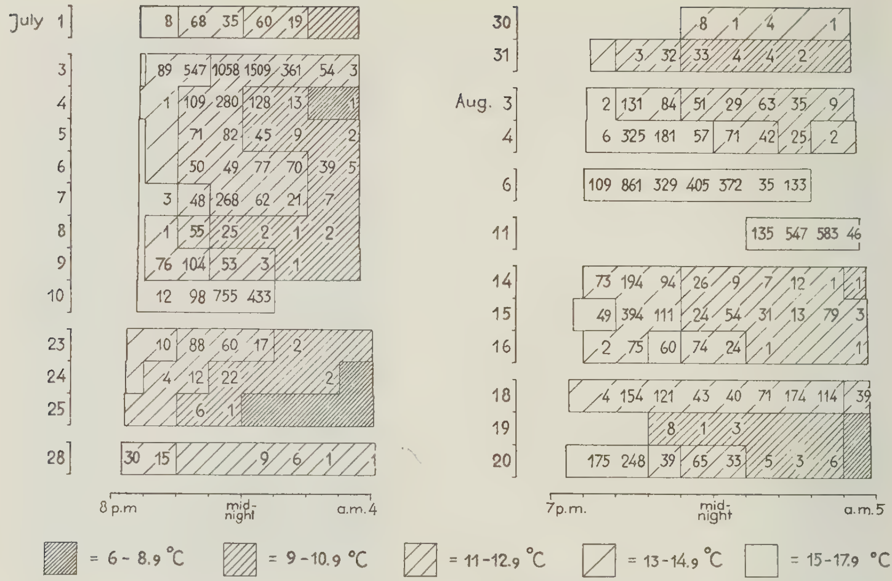


Fig. 57. Relation during calm hours between catch (no. of specimens) of the *Psychodidae* in trap A and temperature, Åkarp, July—August 1952.

Note: The cup anemometer did not work reliably during the night of July 3. It is not quite certain, therefore, that all the hours of this night were calm.

Since females of *Pand. heparana* only rarely came into the traps (cf. table 16 [p. 223]), they are not discussed here. Regarding the males of *Pand. heparana* and the two sexes of *Spil. ocellana*, the figures from 1952 indicate a close relationship between the activity and the temperature. Most of the specimens came into the traps at high or fairly high temperatures. At temperatures below 11 °C only occasional specimens appeared. It is particularly worth noting that no specimens of the two species entered the traps during the night of July 25, 1952. This night was calm and unusually cold for the season. The emergence experiments and the population experiments (cf. p. 180 ff.) indicate that adults of both sexes of the species occurred during this night in large numbers in the field.

In 1953 *Pand. heparana* was only captured in the traps at high or fairly high temperatures. With the exception of a few specimens the same applies to *Spil. ocellana*. However, in this year the night temperature, during the part of the season when adult moths of the two species occurred in the field, only occasionally fell below 13° (cf. fig. 51 [p. 255]).

Because each of the remaining fruit leaf tortricid species was captured only in small numbers or was abundant only during a short period of the season it is not possible to decide on the basis of the experiments to what extent the activity of these species is influenced by the temperature. In

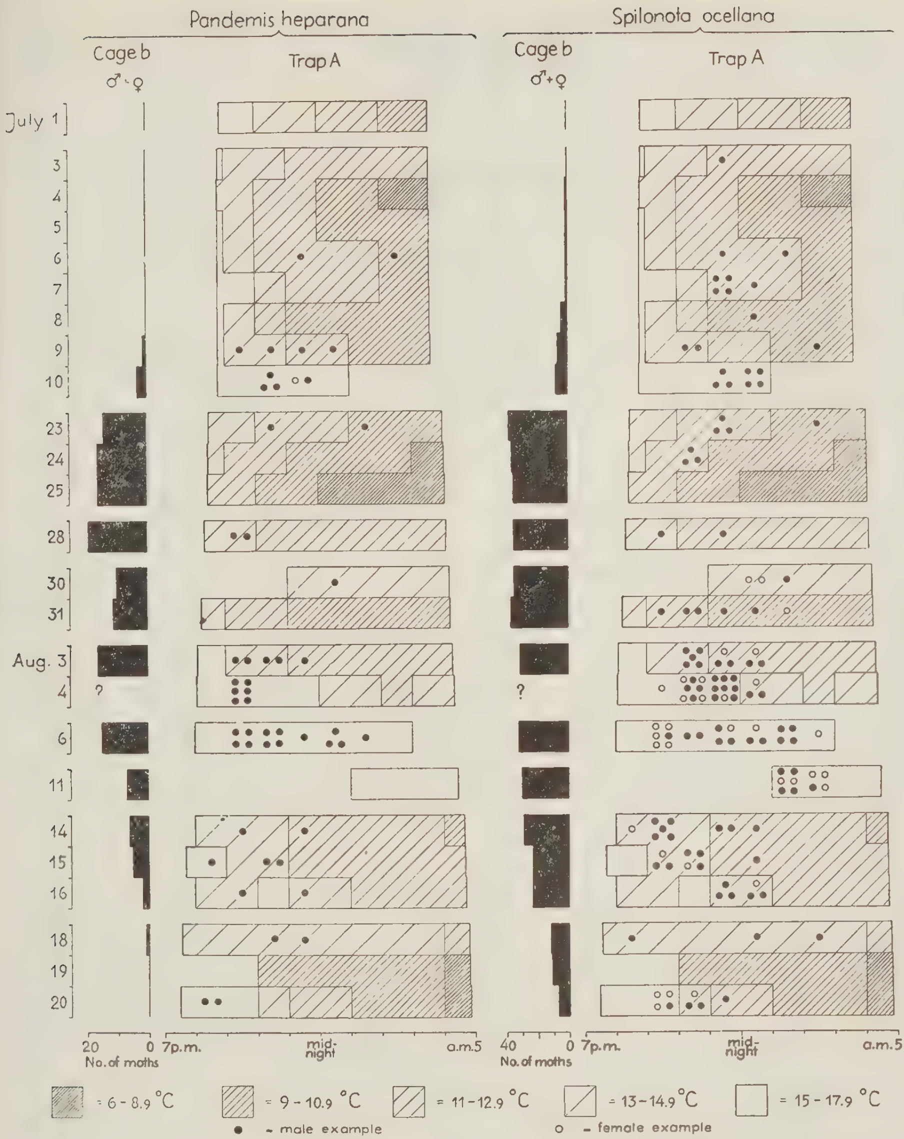


Fig. 58. Relation during calm hours between catch of two fruit leaf tortricid species (*Pand. heparana* and *Spil. ocellana*) in trap A and temperature, Åkarp, July—August 1952. For further explanation see text.

Note: Wind conditions during night of July 3 are not exactly known (cf. fig. 57).

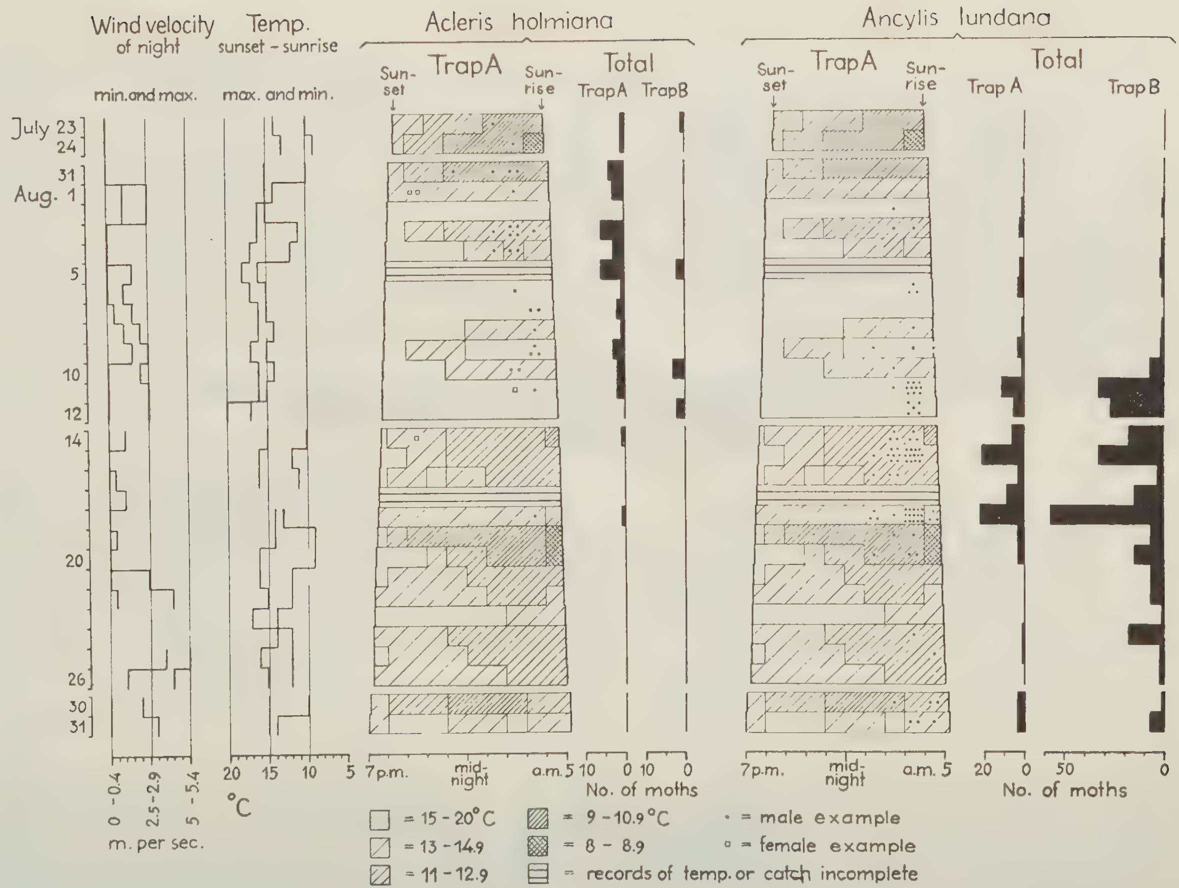


Fig. 59. Relation during some nights in July—August 1952 between catch of two tortricid species (*Acleris holmiana* and *Ancylis lundana*) and temperature.

several species, e. g. in *Pand. ribeana, Cac. podana* and *Acr. naevana,* specimens came into the traps mainly at high or fairly high temperatures (cf. figs. 50—51). Several times, however, both *Arg. variegana* and *Acl. holmiana* were captured at 9 ° or 10 °C. But on the whole fruit leaf tortricid moths occurred only rarely at temperatures below 11 °.

Fig. 59 shows the catch of two tortricid species, *Acleris holmiana* and *Ancylis lundana,* in relation to the temperature during some nights in July —August 1952. As can be seen, specimens of both species were captured at largely varying temperatures.

From fig. 39 (p. 227) it will be seen that *Spil. ocellana* in 1952 was most abundant in the first two weeks of August in trap A, in the second week of August in trap B. Fig. 39 also shows that the same species in 1953 was most abundant in the last week of June and in the first three weeks of July in trap A, in the third and in the fourth week of July in trap B.

It has already been explained that the orchard in which trap B was operated in 1952—1953 was laid out in the autumn of 1951 only, on an area where there were no trees in the summer of 1951 (cf. p. 219). No doubt, the *Spilonota* specimens recorded in trap B in 1952 had with few, if any exceptions "migrated" into the area under discussion. The results of the trap experiments indicate that "immigrants" dominated the *Spilonota* catch in trap B also in 1953.

The catch figures point to the fact that in the two years mainly "old" *Spilonota* adults flew to the area. In this connection it may be repeated that two of the *Spilonota* males which were marked and released in the Substation orchard in 1953 were recovered in trap B (cf. table 19 [p. 230]). One male was caught on the 12th night after its release, the other male on the 23rd night after its release.

During the night of Aug. 12, 1952, the conditions for "migration" of *Spil. ocellana* to the area seem to have been unusually favourable. This night was the warmest night in July—August 1952 with a maximum temperature of 20 ° and a minimum of 17 °C. The wind direction, judging from the observations made at Malmö Airport (cf. p. 240), was southwesterly. All the hours, from 8 p. m., were slightly or moderately windy.

A total of 17 males and 8 females of *Spil. ocellana* came into trap B during the above night. During all the other nights in the summer of 1952 *Spil. ocellana* gave only a total of 38 specimens in trap B: viz. 26 males distributed among 13 nights and 12 females distributed among 11 nights.

Humidity

Williams (1940) presents data suggesting to some degree that a "high" relative humidity is favourable but a "low" relative humidity unfavourable to the activity of many insects. Larsen (1943) made observations indicating to a certain extent that a "high" saturation deficiency from time to time prohibits activity of various noctuid moths. Stirrett (1938), in studying the corn borer, *Pyrausta nubilalis,* compared light trap captures with the saturation deficiency but found no correlation.

Table 23. Daily maximum and minimum temperatures (°C), Åkarp, September 1952. Thermograph records. — Scr. = thermometer screen. Sh. = shelter at bottom of trap A.

Sept.	Max. temp.			Min. temp.			Sept.	Max. temp.			Min. temp.		
	Scr.	Sh.	Diff.	Scr.	Sh.	Diff.		Scr.	Sh.	Diff.	Scr.	Sh.	Diff.
1	22	*		13	13	0	16	17	15	+2	12	12	0
2	18	17	+1	11	11	0	17	16	15	+1	9	9	0
3	16	15	+1	10	10	0	18	16	14	+2	8	8	0
4	17	15	+2	10	10	0	19	14	14	0	5	6	—1
5	17	16	+1	9	9	0	20	14	13	+1	7	8	—1
6	13	12	+1	5	6	—1	21	11	11	0	7	7	0
7	16	15	+1	4	5	—1	22	11	*		7	6	+1
8	17	*		8	8	0	23	12	12	0	11	11	0
9	18	17	+1	4	4	0	24	14	13	+1	12	12	0
10	17	15	+2	8	8	0	25	13	12	+1	10	10	0
11	15	15	0	9	9	0	26	12	12	0	10	11	—1
12	17	16	+1	5	5	0	27	13	13	0	5	6	—1
13	17	15	+2	4	4	0	28	15	14	+1	7	6	+1
14	18	16	+2	3	4	—1	29	14	*		8	8	0
15	18	*		2	2	0	30	14	13	+1	9	9	0

* = Data missing.

At Åkarp the relative humidity was recorded both in 1952 and in 1953 (but not in 1951). A hair hygrograph (W. Lambrecht) was exposed about 3 m. from the ground in a shelter at the bottom of light trap A. The walls of the shelter consisted of overlapping wooden ribs. The arrangement of the ribs admitted air but excluded sun and rain (cf. fig. 33 [p. 214]).

Since humidity is intimately bound up with temperature it can be mentioned that a bimetallic thermograph (Haenni & Co.) was also used in the above shelter, but only during the period Sept. 1—Oct. 15, 1952. On the basis of the records from this period it can be concluded that the night temperature was, generally at least, the same or almost the same in the shelter at the bottom of the trap as in the thermometer screen discussed on p. 259. Table 23 shows the daily maximum and minimum temperatures in the two places during September 1952.

The hygrograph was tested by means of a psychrometer, usually once a week. During the test period the instruments were kept in the wind tunnel mentioned on p. 242. They were exposed to an air current of a velocity of about 1 m. per sec. Table 24 shows the results of the tests made in July—August 1952, and in June—July 1953. The figures indicate that the accuracy of the hygrograph was on the whole good. However, the registrations from the six first days of July 1952 are unreliable and have therefore not been used in the analysis of the light trap captures.

The humidity figures in the graphic representation and in the following text are according to the hygrograph registrations. The data for individual hours are average figures for the various periods.

Table 24. Accuracy tests of the hygrograph. Hygr. = rel. hum. (%) as indicated by the hygrograph. Psychr. = rel. hum. (%) as indicated by the psychrometer.

Tests in 1952				Tests in 1953			
Date	Hygr.	Psychr.	Diff.	Date	Hygr.	Psychr.	Diff.
July 7	74	63	+11	June 2	58	58	0
14	58	64	— 6	8	57	57	0
21	59	60	— 1	15	72	72	0
28	65	70	— 5	22	72	77	—5
Aug. 4	65	67	— 2	29	66	71	—5
11	72	73	— 1	July 6	82	85	—3
18	74	71	+ 3	13	57	58	—1
25	69	64	+ 5	20	61	64	—3
				27	68	66	+2
				Aug. 3	62	62	0
				10	75	71	+4
				17	63	64	—1
				24	75	77	—2

At sunset the relative humidity was often lower than 75 per cent. Within 60 minutes after sunset, however, the relative humidity generally increased to figures above 80 per cent. At midnight the relative humidity was for the most part higher than 85 per cent, at sunrise usually higher than 90 per cent.

The data in figs. 50—51 (pp. 254—255) indicate the relation of the catch in trap A to the relative humidity (fig. 50 for the *Psychodidae*, the *Lepidoptera* and for some fruit leaf tortricid species in the period July 7—Aug. 20, 1952; fig. 51 for the *Lepidoptera* and for some fruit leaf tortricid species in the period June 10—July 31, 1953). As can be seen, the data give no evidence to show that the changes in the relative humidity between the different nights influenced the activity of the insects.

Fig. 60 shows the catch of the *Psychodidae* in trap A in relation to relative humidity and temperature. All the data are for calm hours, 10 p. m.—2 a. m., during the period July 7—Aug. 31, 1952. It will be seen that there is no clear correlation between the captures and the relative humidity.

Fig. 61 shows the relation of the catch of males of *Spil. ocellana* in trap A to relative humidity and temperature. Only calm hours, 10 p. m.—2 a. m., are taken into account, and only the period July 23—Aug. 16, 1952. Throughout this period male adults of *Spil. ocellana* were no doubt abundant in the field (cf. the emergence experiments and the population experiments, p. 180 ff; see also fig. 47 [p. 247]). The data in fig. 61 indicate no correlation between the catch and the relative humidity.

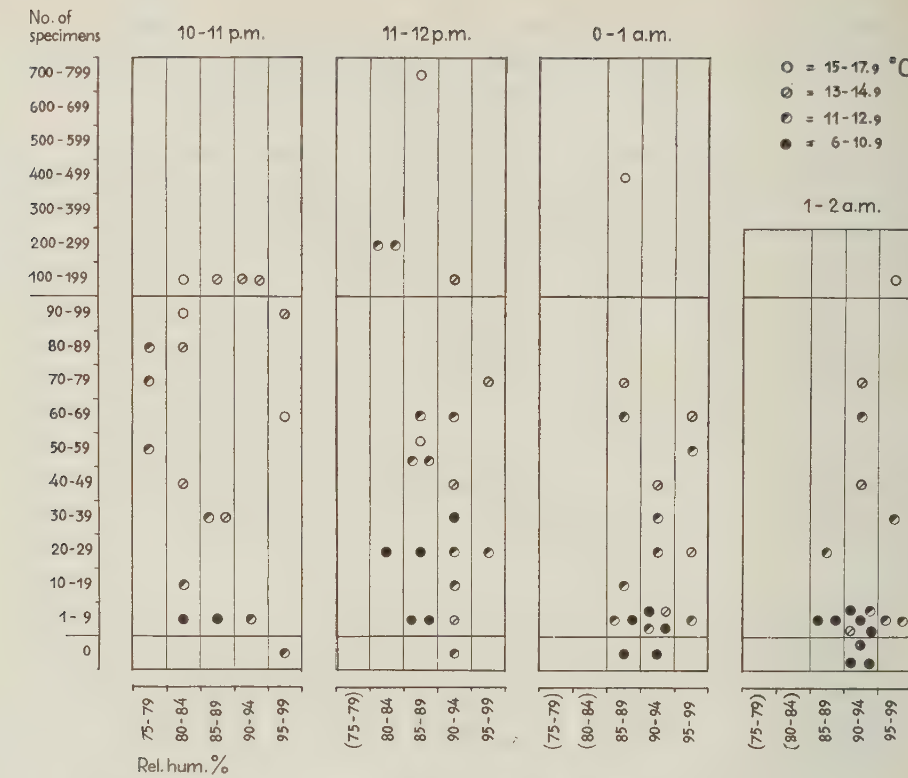


Fig. 60. Relation between catch of the *Psychodidae* in trap A, temperature and relative humidity during calm hours, 10 p. m.—2 a. m., July 7—Aug. 31, 1952. Each circle = one hour (one 60 minute period).

Precipitation

Larsen (1943), in her paper on the importance of master factors for the activity of adult noctuids, pays attention also to the effect of precipitation. She states that "a fine drizzling rain" does not, as a rule, give rise to a decrease of activity at first, the contrary being the case. "A regular downpour", however, according to her observations, will always have an inhibiting effect.

Stirrett (1938) discusses the behaviour of the corn borer, *Pyrausta nubilalis,* in relation to rain. On several occasions he observed the moth in flight during "light" rain; apparently never, on the other hand, during "heavy" rain.

At Åkarp a standard rain gauge was used in 1952. The apparatus was situated on open ground in the Substation garden. Readings were not made on Sundays but otherwise once a day (at 9 a. m.). Table 25 shows the amount of rain recorded in July—August 1952.

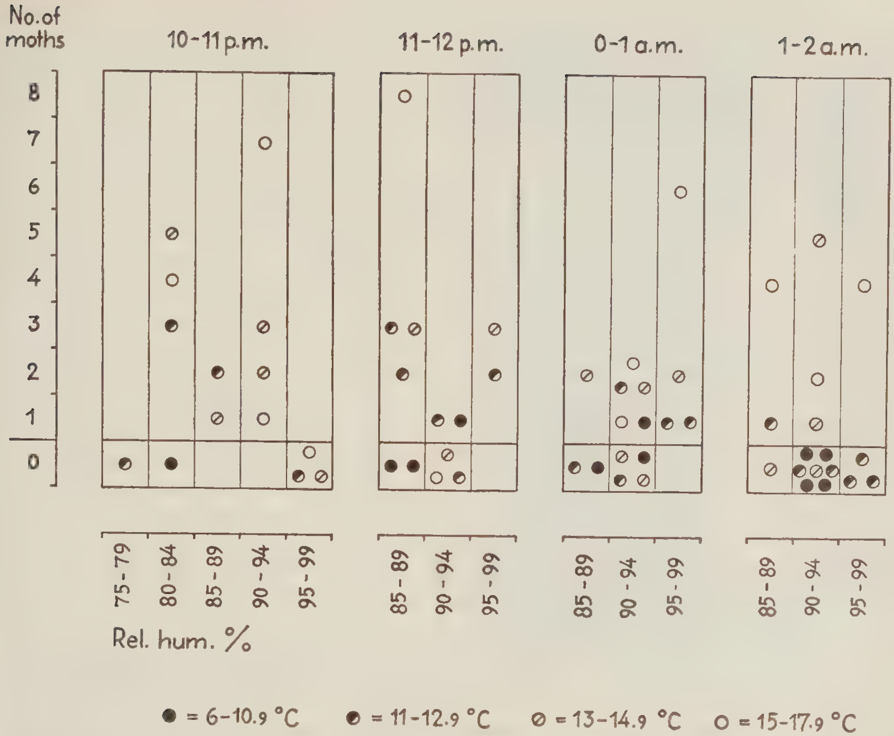


Fig. 61. Relation between catch of *Spilonota ocellana* (males) in trap A, temperature and relative humidity during calm-slightly windy hours, 10 p. m.—2 a. m., July 23 -Aug. 16, 1952. Each circle = one hour (one 60 minute period).

It will be seen in table 25 that more than 30 mm. rain fell from 9 a. m. on July 28 to 9 a. m. on July 29, 1952. As shown by fig. 46 (p. 245), all the hours of the night of July 28 were calm. These circumstances, combined with the catch results, create the suspicion that in the period 10—12 p. m. on July 28 heavy rain occurred, inhibiting the activity of various insects. In trap A, during the night in question, a total of 697 insect specimens were captured in the period 8—10 p. m., a total of 213 specimens in the period 0—2 a. m., but only 45 specimens in the intervening period, 10—12 p. m.

The remaining calm nights in July—August 1952 showed with few, if any exceptions no precipitation. As indicated by the figures in table 25, several of the windy nights (e.g. the nights of July 14 and 22, Aug. 1, 8 and 13; cf. fig. 46) were also dry.

In 1953 a precipitation recorder, type SMHI (= Swedish Meteorological and Hydrological Institute), was exposed on open ground in the Substation orchard. The apparatus, which has been fully described by Slettenmark (1932), is shown in fig. 62. A writing stylus records the amount and the rate of precipitation on a paper mounted on a rotating drum. On the whole,

Table 25. Precipitation at Åkarp, July—August 1952.

Period		Rain in mm.	Period		Rain in mm.
from 9 a. m. on	to 9 a. m. on		from 9 a. m. on	to 9 a. m. on	
July 1	July 11	0·0	Aug. 4	Aug. 7	0·0
11	12	26	7	8	7
12	14	5	8	9	0·0
14	16	0·0	9	11	2
16	17	8	11	12	3
17	18	6	12	13	1
18	19	19	13	16	0·0
19	21	5	16	18	6
21	22	0·5	18	22	0·0
22	25	0·0	22	23	1
25	26	0·4	23	25	0·0
26	28	5	25	26	0·5
28	29	32	26	27	3
29	30	0·3	27	28	8
30	31	2	28	29	2
31	Aug. 1	0·4	29	30	0·2
Aug. 1	2	0·0	30	Sept. 1	0·5
2	4	1			

the apparatus worked satisfactorily, particularly in calm weather. In favourable cases a precipitation amount as low as 0.2 mm. could be read.

The above apparatus was in continuous use in the Substation garden from early June to early October 1953. Rain fell in the nights of June 18, July 7, 9, 13, 17, and 30. For the remaining nights, June 15—July 31, 1953, the available data indicate no precipitation.

Unfortunately the studies give but little information about the relation between flight activity of fruit leaf tortricids and wet weather conditions. In the night of June 18, as in the night of July 9, only about 0.3 mm. rain was recorded; in both cases the rain fell too late in the night (after 1 a. m.) to be of interest in the present connection. In the night of July 30 about 2.4 mm. rain were recorded; it occurred early in the night, before 10 p. m. (mainly at about 9 p. m.); the catch of the *Lepidoptera* was fairly low (23 specimens in trap A, 29 in trap B); probably, however, the wind conditions at the trap during several of the hours of this night were unfavourable for insect activity (cf. fig. 51 [p. 255]).

The figures from the nights of July 7, 13 and 17 merit more detailed attention. A discussion of the precipitation conditions and the catch (*Lepidoptera* in trap A) in these nights follows:

On July 7 the weather was wet in the evening from about 6 to 8:15 p. m. (total amount of rain about 2.2 mm.), also in the night from about 0:20 to 2:20 a. m. (total amount about 0.8 mm.). The catch was high in the hours 10—12 p. m., including e.g. 6 specimens of *Acr. naevana,* 3 of *Pand. hepa-*

Fig. 62. The precipitation recorder.

rana, 1 of *Cac. rosana* and 1 of *Pand. ribeana.* After midnight no fruit leaf tortricids and only few other moths were captured. The second half of the night, however, was much more windy than the first half. This is more than sufficient to account for the marked drop in the catch.

During the night of July 13 the weather was wet towards the end of the hour 9—10 p. m. The rate of rainfall was about 0.6 mm. per 60 minutes, the total amount about 0.2 mm. The catch was high, even in the hour 9—10 p. m. Among the fruit leaf tortricids 3 specimens of *Pand. heparana* were captured in the hour 9—10 p. m.; 3 specimens of *Acr. naevana,* 1 of *Cac. rosana* and 5 of *Spil. ocellana* in the hour 10—11 p. m.

In the night of July 17 the precipitation recorder did not give any clear record of rain. Nevertheless, as shown by direct observations, there was a fine drizzle, lasting 5 or 10 minutes, during the early part of the hour 10—11 p. m. Most of the night was calm and numerous moths and other insects came to the trap, even during the rainy period. With regard to fruit leaf tortricids it was observed that 2 specimens of *Pand. heparana* arrived at the trap during the rain; also that several specimens of the same species, 1 female of *Acl. holmiana* and about 10 specimens of *Spil. ocellana* appeared during the 60 minute period immediately following the rain.

It can be mentioned that rain fell continuously during the night of Aug. 20, 1953, from sunset to after 1 a. m. During this rainfall several moths entered trap A (and probably also trap B). The most abundant species was the noctuid *Rhyacia*

c-nigrum, which gave (in trap A) 4 males and 1 female in the period 10—11 p. m., 4 males in the period 11—12 p. m., and 6 males in the period 0—1 a. m. The rate of the rain varied considerably, during the first of the above three hours between about 0.1 and 0.4 mm. per 60 minutes, during the second hour between about 0.6 and 2.2 mm. per 60 minutes, and during the third hour between about 1.0 and 1.6 mm. per 60 minutes.

In 1957, on the night of Aug. 16, a watch was kept on trap A from 11:30 p. m. to 0:30 a. m. Light rain fell throughout this period (total amount about 0.2 mm.). During the rainfall more than 300 insect specimens were caught in the trap, mostly *Diptera,* but also many *Lepidoptera,* among them 4 males of *Spil. ocellana.*

Moonlight

It has been pointed out by several authors that moonlight decreases the efficiency of light traps. Strickland (1922), for example, states that bright moonlight causes light traps to be ineffective for trapping the noctuid *Porosagrotis ortogonia.* In principle Marchal (1912) indicates the same for the two vine tortricids, *Clysia ambiguella* and *Polychrosis botrana.*

Williams (1936, 1940) compared light trap captures of different insect groups with the moon phases. He found that the captures of the *Noctuidae* showed a periodicity which closely corresponded to the changes in moonlight. Generally, the periods of maximum catch during the season coincided with the no moon periods. However, with regard to several other insect groups, e.g. the *Psychodidae,* Williams did not succeed in finding any significant correlation of the captures to the moon.

In his accounts of the relation between the catches and the moon Williams gives no exact data of the wind conditions. Neither do his papers contain figures showing the relationship of the catch of individual species to the moon phases. For various reasons, e.g. the differences between separate species in the seasonal appearance of the adults, the results of several of the analyses made by Williams are somewhat surprising.

The uppermost diagram in fig. 63 is drawn after a graph published by Williams (1936) and shows the noctuid captures in a light trap at Rothamsted, June 1—Oct. 20, 1935 (cf. p. 222). The times when there was full moon and no moon are also indicated. The remaining data in fig. 63 show the noctuid captures in trap A at Åkarp, June 18—Oct. 14, 1952, and June 4—Oct. 9, 1953, in relation to the moon phases and some other factors.

The different captures are represented logarithmically in fig. 63, according to a method proposed by Williams (1935, 1936, 1940). To avoid minus infinity, i.e. the log of zero, unity is added to each value before converting into log. The log of 1 is zero and corresponds to a capture of zero; the log of 2 is 0.301 and corresponds to a capture of 1 specimen, etc.

It will be seen in fig. 63 that only the captures from Rothamsted show a

periodicity closely coinciding with the moon phases. At Åkarp large noctuid captures were obtained also during nights characterized by bright moonlight, e.g. during the clear nights early in July 1953.

Of the noctuids the most abundant species in the traps at Åkarp was *Rhyacia c-nigrum* (cf. table 17 [p. 224]). In 1953 this species mainly came into the traps late in June and early in July, in the latter two thirds of August, in September and early in October. The captures of *Rhyacia c-nigrum* during these periods, also the moon phases and some other factors, are illustrated in fig. 64. As can be seen, the data give no evidence to show that there was any lunar effect. It is true that fairly few specimens came into trap A during the moon period late in August, but this was no doubt a result of windy weather (cf. the wind curve, fig. 64). During the same period large numbers of specimens were caught in trap B (cf. fig. 64). It can be assumed that the wind velocity during this period was much lower at trap B than at trap A (cf. p. 248).

The moon phases are also shown in figs. 46—47 and 50—51. No lunar effect can be discerned, either for the *Psychodidae* (cf. fig. 46 [p. 245]), the *Lepidoptera* (cf. figs. 50—51 [pp. 254—255]) or for fruit leaf tortricids (cf. fig. 47 [pp. 246—247] and figs. 50—51).

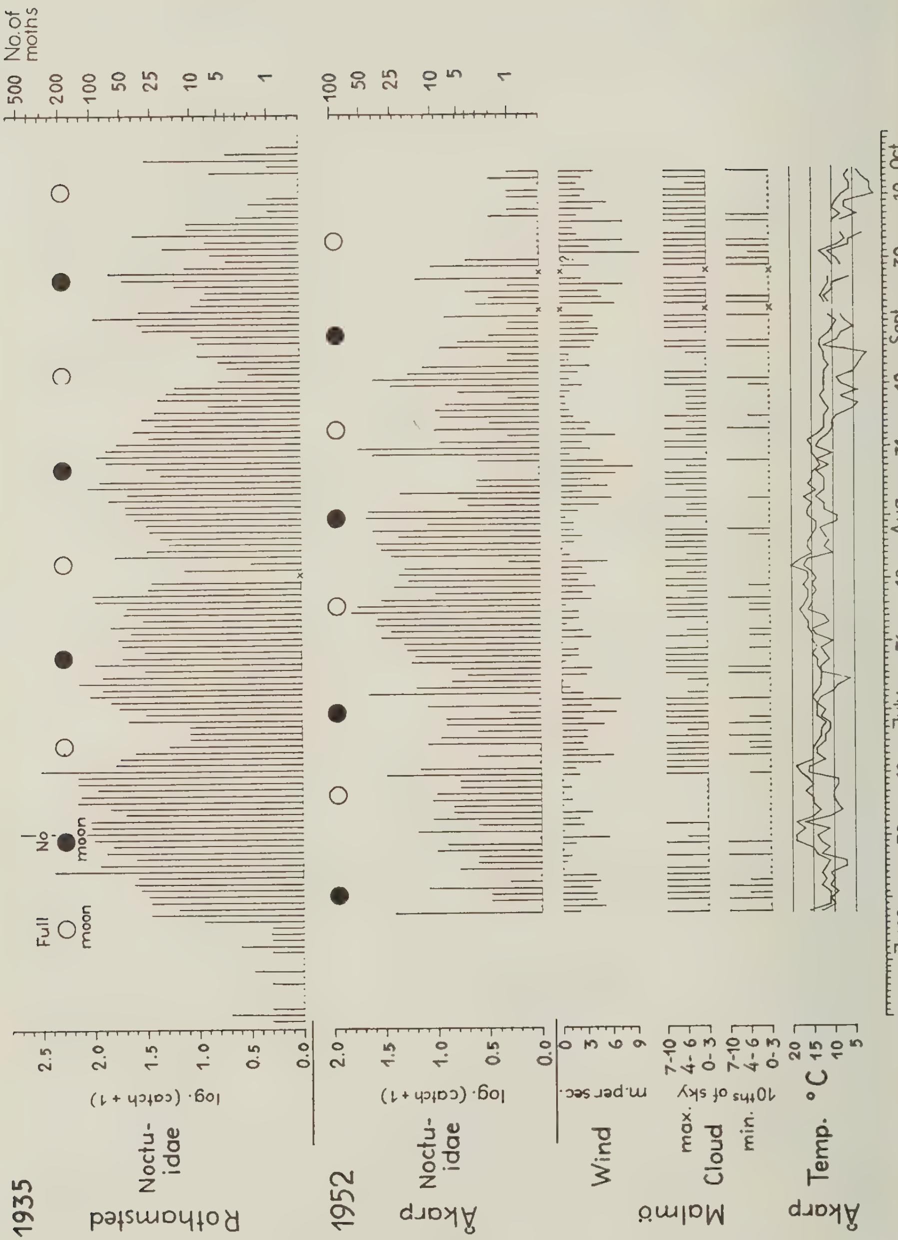
Of course, it can not be concluded from the above that the moon had no effect at all. Probably the strong influence of the wind velocity masked the effect of many other factors, including the moonlight.

Other factors

No doubt the cloud indirectly, through its effect upon the temperature, influenced the activity of the insects considerably. As is well known, cloudy nights show a tendency to be darker than clear nights. Although not proved by the analysis, it might be suspected that this circumstance, too, affected the catch results.

Visibility also merits attention here. This factor was not studied at Åkarp, but figures showing the visibility during part of the night at Malmö Airport (for location see p. 240) are available. They indicate that the variations in visibility were on the whole small and of no great importance in connection with the light trap operations (cf. fig. 65.).

The air pressure only varied between fairly close limits. The Swedish Meteorological and Hydrological Institute has kindly placed at my disposal figures of the air pressure (reduced to zero °C, normal gravity, and sea-level) at 7 p. m. at Malmö. In fig. 65 the pressure figures for the period July 1—Aug. 20, 1952, can be compared with some of the catch figures (*Psychodidae, Lepidoptera* and *Spil. ocellana*) from the same period. It will be seen that the data give no indication of any direct effect of the air pressure upon the activity of the insects.


1935
Rothamsted
Noctu-idae
log. (catch + 1)
0.0 0.5 1.0 1.5 2.0 2.5
No. of moths
1 5 10 25 50 100 200 500
Full moon
No moon
1952
Åkarp
Noctu-idae
log. (catch + 1)
0.0 0.5 1.0 1.5 2.0
1 5 10 25 50 100
Wind
m. per sec.
0 3 6 9
Malmö
Cloud
max.
min.
10ths of sky
0-3 4-6 7-10
Åkarp
Temp.
°C
5 10 15 20
1 June 10 30 July 10 31 Aug. 10 31 Sept. 10 30 Oct. 10

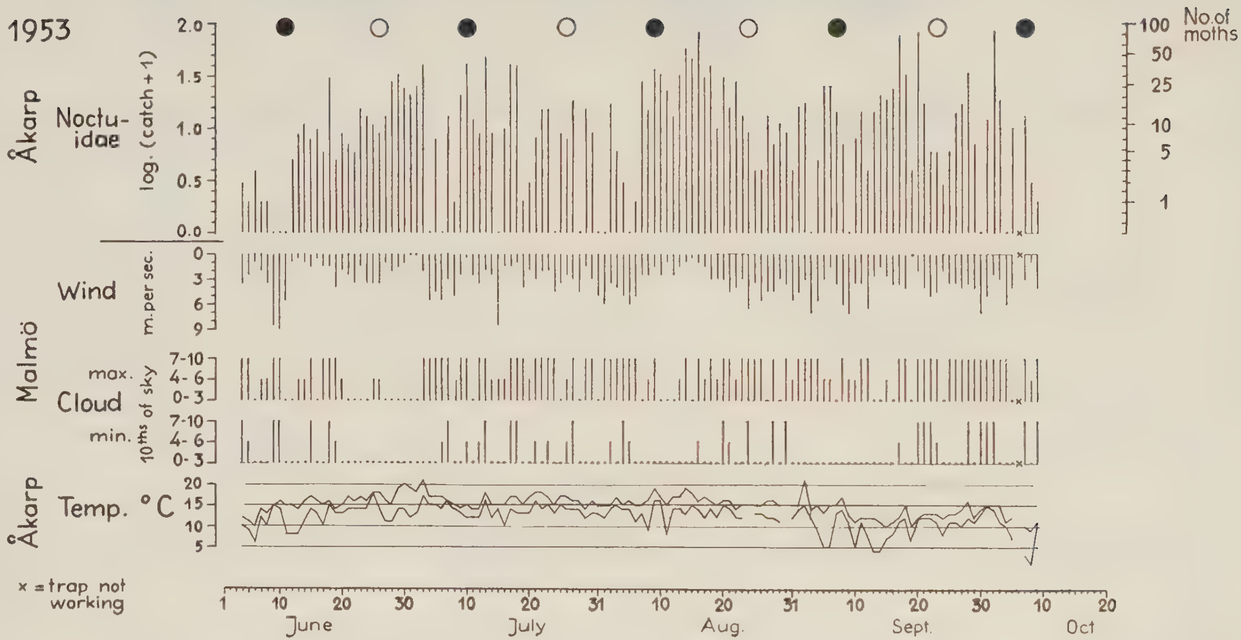


Fig. 63. Abundance of the *Noctuidae* in light traps in relation to moon phases. Catch data from 1935 = trap at Rothamsted north of London (after Williams 1936). Catch data from 1952—1953 = trap A, Substation orchard, Åkarp.

Note: As seen, meteorological data from 1952—1953 are also given. Data of *wind vel.* show calculated average wind vel., sunset — 1 a. m., Malmö Airport (cf. p. 250 ff.). Data of *cloud* show max. and min. cloud, sunset — 1 a. m., according to observations, Malmö Airport (cf. p. 240). Data of *temp.* show max. and. min. temp., sunset — sunrise, according to thermograph, Substation garden, Åkarp (cf. p. 260).

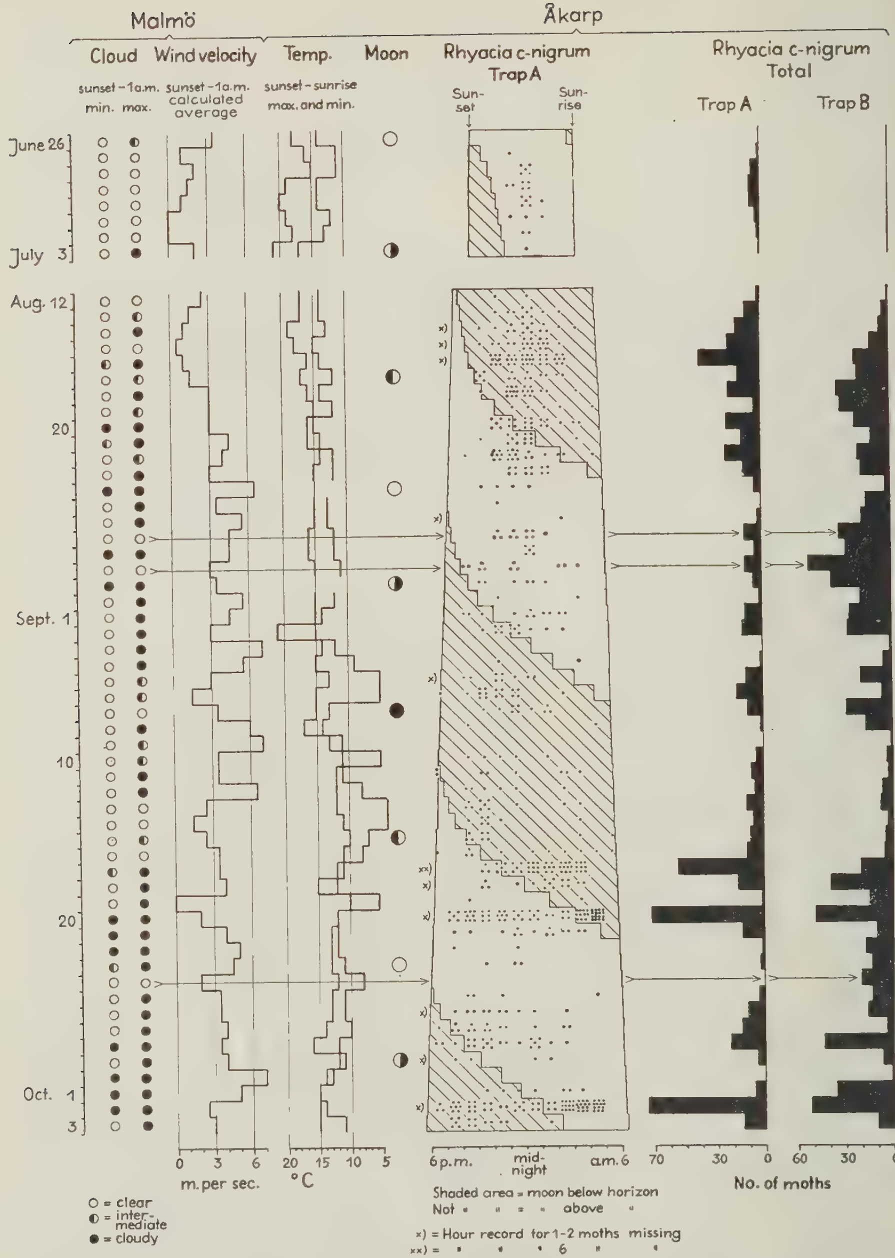


Fig. 64. Catch of *Rhyacia c-nigrum* in relation to moon and some other factors, June 26—July 3 and Aug. 12—Oct. 3, 1953. Each dot (in graph showing night distribution of catch in trap A) = one specimen.

Note: The data of night distribution of catch, Oct. 2, are approximative.

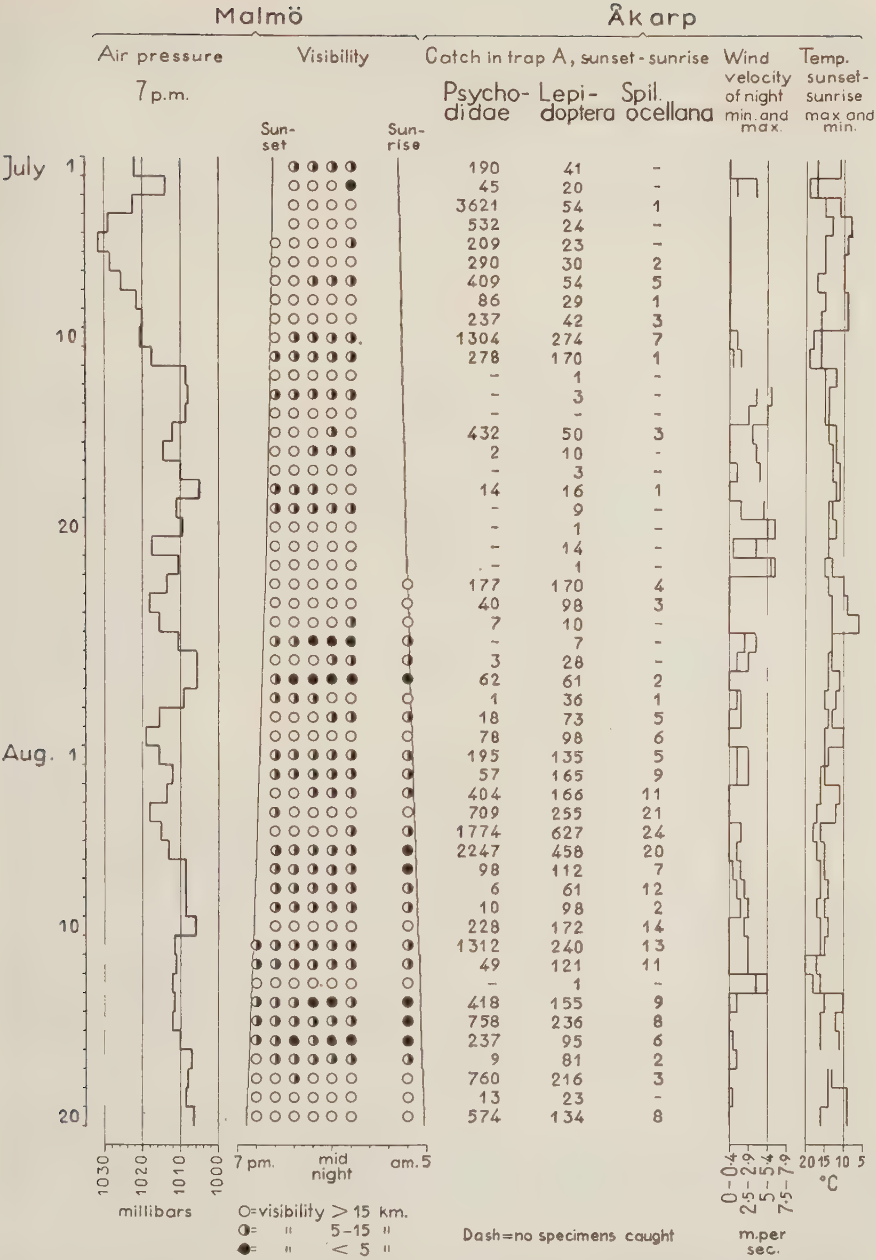


Fig. 65. Catch (no. of specimens) of *Psychodidae*, *Lepidoptera* and *Spilonota ocellana* in trap A in relation to air pressure, visibility and some other factors. July 1—Aug. 20, 1952.

The dew conditions in the Substation orchard at Åkarp were not kept under observation. It can be mentioned that Stirrett (1938) studied thoroughly the flight activity of the corn borer, *Pyrausta nubilalis,* in relation to dew. He found no correlation between the two factors.

Thunder and lightning rarely occurred. At Malmö Airport, according to the observations made there, thunderstorms did only occur on one of the nights in July—August 1952, and only on two of the nights in June—August 1953.

Summarizing remarks

The successive fluctuations in the catch were caused partially by the successive changes in the adult population, partially by the influence of environmental factors upon the behaviour of the adult insects. In the following brief survey only this latter environmental influence is dealt with. Of the captures solely those of the *Psychodidae,* of the males of *Pand. heparana* and of the two sexes of *Spil. ocellana* are discussed.

It is evident that the fluctuations in the catch were largely due to variations in wind velocity. The catch of psychodid specimens, for example, shows a close concentration to calm or only slightly windy periods. The analysis proves that the males of *Pand. heparana* and the two sexes of *Spil. ocellana* are also sensitive to windy weather conditions.

Strictly speaking, it is not shown by the investigations that the wind velocity had a direct effect upon the activity of the insects, i.e. that the mechanical power of air movements influenced flight activity. Data from the summer of 1956 suggest that the evaporative power of the air in the nights when the light trap experiments took place was always low during calm periods but rapidly increased with increasing wind velocity. Perhaps increased evaporative power of the air frequently caused insects to seek shelter.

Some figures indicating the evaporative power of the air during some nights in 1956 are given in table 26. The evaporation figures are according to an evaporation recorder (W. Lambrecht). The instrument recorded the evaporation from a water surface measuring 250 sq. cm. and occupying a position about 2 m. from the ground in the Substation garden, Åkarp. The water surface was exposed to the open air but shielded from sun and rain.

Moreover, it can be concluded that the fluctuations in the catch were to some extent due to variations in the temperature of the air. Temperatures below 11 or 10 °C caused the catch of psychodid specimens to be low or zero. Such low temperatures also inhibited flight activity in the males of *Pand. heparana.* The same applies to the two sexes of *Spil. ocellana.*

The analysis points to the fact that the fluctuations in the catch of psychodid specimens, of males of *Pand. heparana,* and of the two sexes of *Spil. ocellana* were not at all or only to a limited extent connected with the variations in relative humidity, in moonlight, and in visibility. In addition,

Table 26. Evaporation from a free water surface in relation to wind velocity, relative humidity and temperature during fifteen nights[1] in 1956. All instruments placed in Substation garden, Åkarp, about 35—40 m. south of catching place I (cf. p. 219).

Evaporation = evaporation recorder about 2 m. above ground (cf. text). *Wind velocity* = cup anemometer about 9 m. above ground. *Relative humidity* and *temperature* = hair hygrograph and bourdon thermograph, both about 2 m. above ground in a screen of the type shown in fig. 55 (p. 260).

Note: As can be seen, the fifteen nights are arranged according to wind velocity recorded by cup anemometer.

Date	Wind direction[2]	Average wind velocity[3] m. per sec.	Evaporation (dest. water) per 60 minutes kg. per sq. m.	Average relative humidity %	Average temperature °C
Aug. 23	W.N.W.—N.W.	0·5	0·00	95	10·5
July 10	W.N.W.—N.W.	0·7	0·00	95	13·7
„ 9	W.N.W.—N.W.	0·8	0·00	95	13·2
„ 12	W.—N.N.W.	1·0	0·00	94	13·3
Aug. 28	S.S.W.—W.S.W.	1·2	0·01	98	12·1
„ 29	S.S.W.	1·6	0·01	97	11·8
„ 20	W.S.W—W.	2·8	0·05	90	14·1
„ 8	W.S.W—W.	5·7	0·10	94	14·8
„ 21	W.	5·9	0·11	88	12·9
„ 30	W.	6·5	0·11	91	13·4
„ 19	S.W.—W.	8·7	0·18	97	14·7
„ 15	W.	9·7	0·19	90	12·7
July 26	W.	10·3	0·19	82	15·3
Sept. 28	S.S.W.—W.S.W.	10·6	0·31	83	14·1
Aug. 14	S.W.—W.	10·7	0·18	89	14·2

1 Hour when sun sets and hour when sun rises not considered.

2 Data based on observations made in evening preceding and in morning following the night (at 7 p. m. and 7 a. m. respectively).

3 When wind was S.W.—W. evaporation recorder was exposed to a wind velocity the strength of which was, on an average, about 50 per cent of that simultaneously recorded by cup anemometer.

the studies indicate that the variations in air pressure had little, if any direct effect upon the activity of the insects.

It is quite possible that the activity of insects, e.g. of the *Psychodidae* and of the different fruit leaf tortricid species, is affected by rain. However, judging from the available data, night-rain occurred fairly seldom during the experiments at Åkarp. In connection with the light trap experiments, therefore, the precipitation factor seems to have been of secondary importance.

Comparison of catch from different localities

With the aid of light traps the seasonal appearance of adults of fruit

Fig. 66. Distribution of area (each dot = 10 hectares) of commercial fruit cultivation in southern Sweden according to an inventory made in 1948—1949. After Anjou 1950.

Note: District names entered by present author.

leaf tortricids was studied in several important fruit tree districts in southern Sweden. These studies are dealt with in this chapter.

First, however, some data indicating the geographical distribution of commercial fruit cultivation in Sweden, and also some data of temperature conditions in some localities in southern Sweden, should be given. The data of the fruit cultivation refer to an inventory made in 1948—1949 and are taken from a paper by Anjou (1950). The temperature data have been kindly placed at my disposal by the Swedish Meteorological and Hydrological Institute, Stockholm.

According to the above inventory, the commercial orchards in Sweden contain a total of about 1,372 thousand fruit trees (84 per cent apple, 8 per cent pear, 6 per cent plum, 2 per cent cherry). Most of them, or about 1,007 thousand trees, are to be found in Scania, i.e. in the southernmost province of the country.

In fig. 66 it can be seen that the commercial fruit cultivation in the

Table 27. Average temperature (°C), May—June, in some localities in southern Sweden. For situation of localities cf. map, fig. 67.

	Height above sea-level in m.	May—June 1901—1930	May—June 1951	May—June 1952	May—June 1953
Localities west of long. 13° 30' E.					
Smygehuk	5	11·4	11·7	11·5	13·1
Falsterbo	5	11·9	12·1	11·8	13·3
Hököpinge	17	12·1	—	—	—
Malmö	3	12·4	12·6	12·4	14·4
Lund	36	12·3	12·7	12·2	14·8
Svalöv	72	11·8	12·2	11·8	14·3
Sjöholmen	55	11·3	11·7	11·2	14·0
Ljungbyhed	52	—	12·0	11·6	14·1
Hälsingborg	5	—	12·4	12·1	14·2
Kullen	72	12·0	12·2	11·7	13·9
Barkåkra	42	—	12·2	11·6	13·6
Hallands Väderö	12	12·2	12·4	12·0	13·8
Skånes Fagerhult	115	11·3	11·3	10·2	13·7
Knäred	70	11·3	12·3	11·5	14·2
Genevad	8	12·2	—	—	—
Localities east of long. 13° 30' E.					
Ystad	7	11·6	11·3	11·1	13·2
Hammenhög	50	11·5	11·5	11·1	13·6
Simrishamn	13	10·9	11·1	11·0	12·5
S:t Olof	110	11·4	10·9	11·0	13·8
Björka	25	11·6	12·0	12·1	13·9
Kristianstad	6	12·5	12·5	12·1	14·8
Karlshamn	5	12·0	11·5	11·3	13·4
Hässleholm	50	—	—	11·6	13·9
Osby	76	11·6	—	11·1	—
Ekefors	145	11·5	11·6	11·2	14·0

southern parts of Sweden shows a very marked concentration to four districts. These are the Kivik district in southeastern Scania, the Vånga district in northeastern Scania, the Båstad-Hälsingborg district in northwestern Scania, and the Urshult district in southern Småland.

It is evident that the temperature in spring—early summer, through its effect upon the rate of the larval-pupal development in the different fruit leaf tortricids, determines to a considerable extent the seasonal appearance of the adult moths. In order to give an idea of the temperature conditions in spring—early summer (May—June) in different parts of southern Sweden (mainly in Scania) temperature data from some localities have been summarized in table 27. The figures suggest that the average temperature for May—June is somewhat lower in southeastern Scania than in e.g. western Scania. On the whole, however, the series of data in the table indicates only fairly small local variations in temperature.

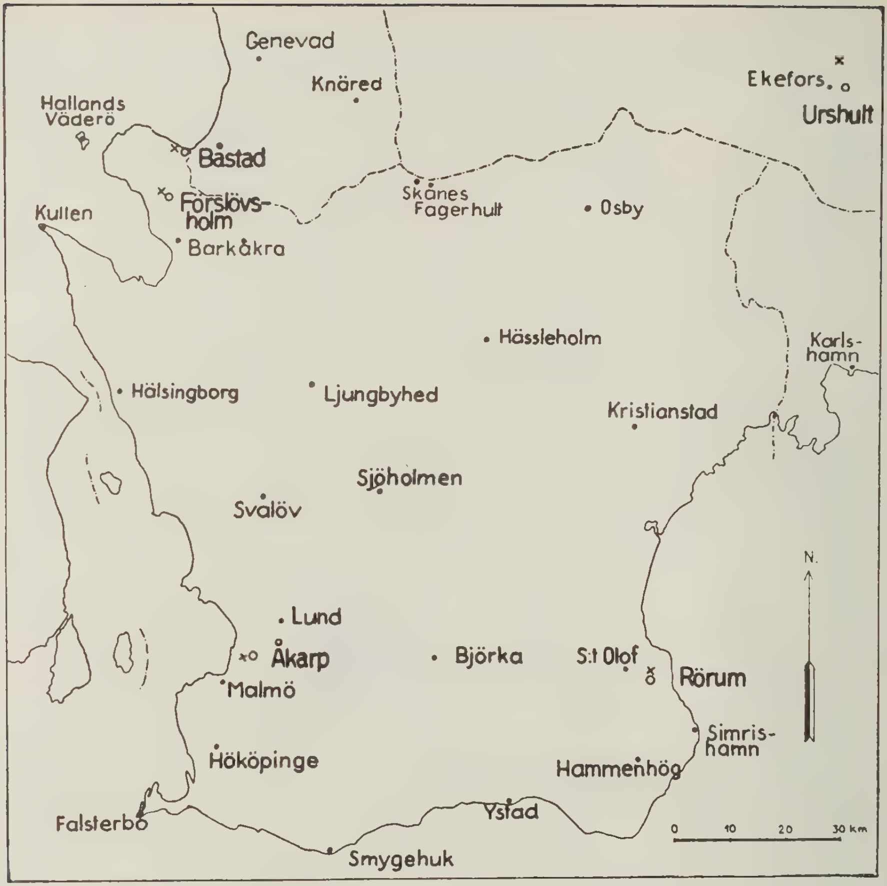


Fig. 67. Map of Scania and surrounding areas. Black dots = localities mentioned in table 27. Crosses = localities where light trap experiments took place. (Plant Protection Substation, Åkarp; Bjäredalen, Förslövsholm; Småryd, Båstad; Eriksdal, Rörum; Kurrebo, Urshult).

The light trap experiments referred to in the introduction of this chapter were carried out in 1951—1953. Disregarding the light trap experiments at Åkarp (which have already been discussed in detail [cf. p. 212 ff.]), three traps were used. They were of the model shown in fig. 68, the catching mechanism being principally the same as in the traps exposed at Åkarp (cf. p. 213). Each of the three traps was equipped with a clear standard light bulb (200 watt). No attempt was made to measure the voltage variations in the respective circuits from which the current was taken; nor was any kind of current regulating device employed in the traps. The current was

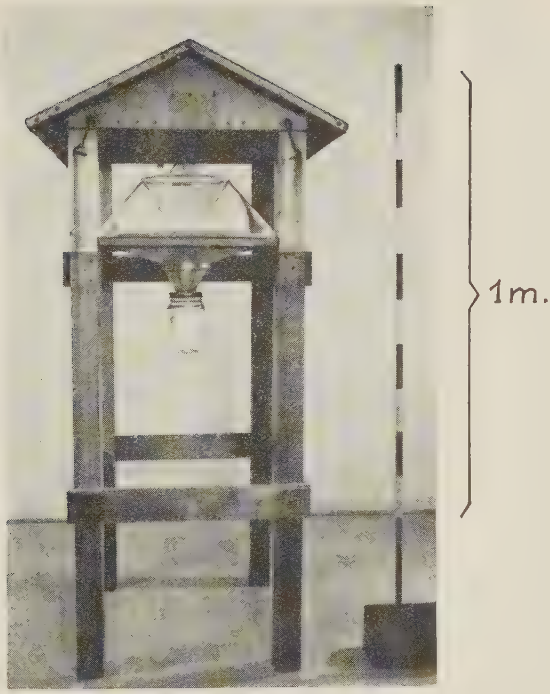


Fig. 68. Light trap used in northwestern Scania, 1951—1953.

switched on and off automatically and the traps were operated during the whole night, i.e. from sunset to sunrise.

One of the above three traps was in 1951 exposed in a place located about 30 m. above sea-level in an apple plantation in the orchard of Bjäredalen, Förslövsholm (northwestern Scania; cf. fig. 67); in the following two years the same trap was exposed in a place located about 10 m. above sea-level in an apple orchard at Småryd, Båstad (northwestern Scania; cf. fig. 67). The two remaining traps were not used until 1953; one of them was then exposed in a place located about 30 m. above sea-level in an apple plantation in the orchard of Eriksdal, Rörum (southeastern Scania; cf. fig. 67), the other trap in a place located about 170 m. above sea-level in an apple orchard at Kurrebo, Urshult (southern Småland; cf. fig. 67).[1]

The catch material from the above localities was sent to Åkarp for counting. When examined there, it was found that part of the catch was in a bad condition. Exact data of the number of fruit leaf tortricid specimens caught on certain nights are therefore lacking.

Table 28 gives figures of the catch of some fruit leaf tortricid species in the experiments at Förslövsholm, Båstad, Rörum and Urshult. With regard

[1] For valuable assistance in connection with the studies discussed in this chapter I wish to thank Mr Einar Christiansen, Förslövsholm, Mr Ivar Ericson, Strandbaden, Mr Erik Mårtensson, Rörum, and Mr Nils Östlind, Urshult.

Table 28. Light trap experiments. Catch of fruit leaf tortricids at different places in southern Sweden.

Locality and year	First	Last	No. of nights from which reliable catch figures are available	Number of specimens														
	night of operation			*Arg. variegana*		*Pand. ribeana*		*Cac. podana*		*Acr. naevana*		*Spil. ocellana*		*Acl. holmiana*		*Pand. heparana*		Each of remaining species
				♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	
Förslövsholm 1951	June 11	Aug. 29	72	81	2	26	1	68	0	3	0	61	8	11	1	18	1	<10
Båstad 1952	May 27	Sept. 7	98	11	0	1	0	31	0	0	0	14	0	0	0	25	1	<10
Båstad 1953	June 11	Aug. 31	68	5	0	11	0	10	0	0	0	1	1	0	0	26	1	<10
Rörum 1953	June 9	Aug. 23	67	8	1	30	3	73	1	2	0	0	0	2	0	22	2	<10
Urshult 1953	June 12	Sept. 1	75	18	1	6	0	36	0	38	5	0	0	0	0	4	0	<10

Table 29. Light trap experiments, June 10—Aug. 23, 1951. Catch of Argyroploce variegana, Cacoecia podana, Spilonota ocellana and Plutella maculipennis at Åkarp and Förslövsholm. Å = trap at Åkarp. F = trap at Förslövsholm.

Period	Number of specimens							
	Arg. variegana		*Cac. podana*		*Spil. ocellana*		*Plut. maculipennis*	
	Å	F	Å	F	Å	F	Å	F
June 10—12	0	0[1]	0	0[1]	0	0[1]	4	3[1]
13—15	0[1]	0	0[1]	0	0[1]	0	0[1]	0
16—18	2	3	0	0	0	0	5	14
19—21	2	10	0	0	0	0	8	8
22—24	6	6	0	0	0	0	21	29
25—27	1	11	0	0	0	0	33	20
28—30	1	7	1	0	0	0	9	2
July 1— 3	0	0	0	0	0	0	0	1
4— 6	0	2	0	0	0	0	11	5
7— 9	2	10	5	3	10	0	7	0
10—12	5	9	25	10	16	5	94	5
13—15	2	10	25	7	37	13	11	5
16—18	0	2	1	1	3	3	0	1
19—21	1	6	6	4	17	4	8	7
22—24	1	1	0	4	7	1	7	3
25—27	1	6	11	25	58	20	37	≥45
28—30	0	0	0	1	19	8	16	2
31— 2	0	0	0	0	13	0	6	0
Aug. 3— 5	0	0[1]	15	2[1]	40	1[1]	1	4[1]
6— 8	0	0	1	1	42	0	16	11
9—11	0[1]	0[1]	3[1]	7[1]	15[1]	5[1]	5[1]	10[1]
12—14	0	0	0	1	0	3	2	4
15—17	0	0	0	0	4	1	4	3
18—20	0	0	0	1	8	2	7	5
21—23	0	0	0	1	7	3	11	≥2

[1] Refers to two nights only; catch data from remaining night incomplete or missing.
Note: At Åkarp the first specimens of *Spil. ocellana* were caught on July 8 (6 examples), at Förslövsholm on July 10 (3 examples).

to each trap only the nights from which reliable catch data are available are considered.

In the experiments in the four localities, as seen in table 28, *Cac. podana* was obtained in fairly high numbers, particularly at Förslövsholm and at Rörum. *Arg. variegana* and *Spil. ocellana* were caught chiefly at Förslövsholm. *Acr. naevana* was the most abundant fruit leaf tortricid species in the trap at Urshult but otherwise produced only few specimens.

Table 29 shows the seasonal distribution of the catch of *Arg. variegana, Cac. podana* and *Spil. ocellana,* for comparison also of a tineid moth, *Plutella maculipennis,* at Åkarp and Förslövsholm, June 10—Aug. 23, 1951.

Table 30. Light trap experiments, June 10—Sept. 1, 1952. Catch of Cacoecia podana and Plutella maculipennis at Åkarp (trap. A; cf. p. 213) and Båstad.

Period	Number of specimens			
	Cac. podana		*Plut. maculipennis*	
	Åkarp	Båstad	Åkarp	Båstad
June 10—12	0	0	*1*	0
13—15	0	0	*2*	0
16—18	0	0	*4*	*1*
19—21	0	0	0	*1*
22—24	0	0	0	0
25—27	0	0	*10*	*1*
28—30	0	*2*	0	*1*
July 1—3	*6*	0	*5*	*1*
4—6	*1*	*5*	*4*	0
7—9	*3*	*7*	*19*	*2*
10—12	*16*	*6*	*59*	*28*
13—15	*2*	*1*	*2*	*2*
16—18	0	0	0	0
19—21	0	*2*	0	0
22—24	*1*	*3*	*6*	0
25—27	0	0	*1*	0
28—30	0	*1*	*1*	0
31—2	*1*	*2*	*7*	*2*
Aug. 3—5	*4*	*1*	*23*	0
6—8	*3*	*1*	*10*	*6*
9—11	*2*	0[1]	*2*	*3*[1]
12—14	*1*	0[2]	0	0[2]
15—17	*1*	0[1]	*3*	0[1]
18—20	*1*	0	*3*	*1*
21—23	0	0	0	0
24—26	0	0	0	1
27—29	0	0[1]	0	0[1]
30—1	0	0	0	0

[1] Refers to two nights only.
[2] Refers to one night only.

Tables 30—31 show similar comparisons referring to the experiments in 1952—1953.

As exemplified by the figures in the tables there is, on the whole, a good correspondence in the seasonal distribution of the fruit leaf tortricid catch between the trap at Åkarp (Substation orchard; cf. p. 217 ff.) and the traps used in other localities. From the studies it seems reasonable to assume that there are normally only inconsiderable differences between the fruit tree districts mentioned on the map, fig. 66, as regards the seasonal appearance of the adults of the various fruit leaf tortricids.

Table 31. Light trap experiments. June 10 Aug. 23, 1953. Catch of Pandemis ribeana at Åkarp and Rörum, of Cacoecia podana at Åkarp, Rörum and Urshult, of Acroclita naevana at Åkarp and Urshult, and of Plutella maculipennis at Åkarp, Rörum and Urshult. Å= trap A, Åkarp (cf. p. 213). R = trap at Rörum. U = trap at Urshult.

Period	Number of specimens									
	Pand. ribeana		*Cac. podana*			*Acr. naevana*		*Plut. maculipennis*		
	Å	R	Å	R	U	Å	U	Å	R	U
June 10—12	0	0	0	0	0[2]	0	0[2]	1	24	2[2]
13—15	4	0	0	0	0	0	0	3	54	8
16—18	5	0	1	1	0	0	0	8	17	7
19—21	1	0	1	0	0	0	0	0	8	0
22—24	3	5	1	1	1	0	0	1	13	3
25—27	3	8	4	2	8	0	0	11	41	5
28—30	10	5	19	29	6	8	0	13	47	4
July 1— 3	6	9	19	25	11	10	7	24	66	10
4— 6	0	0[1]	0	2[1]	0	0	1	0	5[1]	3
7— 9	1	3	0	8	2	6	4	0	17	2
10—12	0	1[1]	8	3[1]	0	6	3	2	17[1]	0
13—15	0	0	2	3	1	8	7	11	10	5
16—18	1	0[1]	3	0[1]	2	15	5	4	5[1]	5
19—21	0	0[2]	1	0[2]	0	1	2	3	0[2]	3
22—24	0	1	0	0	1	0	4	1	8	6
25—27	0	0	1	0	2	1	1	1	6	8
28—30	0	0	0	0	0	0	0	1	7	8
31— 2	0	0[2]	0	0[2]	0	0	1	0	0[2]	2
Aug. 3— 5	0	1	0	0	0	0	0	0	6	2
6— 8	0	0	0	0	1	0	0	4	6	2
9—11	0	0	1	0	0	0	6	4	17	3
12—14	0	0	0	0	1	0	2	4	1	2
15—17	0	0[1]	0	0[1]	*	1	*	8	2[1]	*
18—20	0	0	0	0	0[2]	0	0[2]	1	2	0[2]
21— 23	0	0[1]	0	0[1]	*	0	*	2	4[1]	*

[1] Refers to two nights only.
[2] Refers to one night only.
* Catch figures missing.

Note: At Åkarp the first specimens of *Acr. naevana* were caught on June 29 (3 examples), at Urshult on July 2 (3 examples).

Outlines for an advisory service based on light trap experiments

In connection with the studies accounted for above an advisory service concerning the times suitable in Scania for summer application against fruit leaf tortricid species hibernating in the larval stage (cf. p. 161) was started. This service is discussed in this chapter.

A spraying schedule for summer control will first be presented.

Spray no. 1. In early "high" summer. Any suitable insecticide, e.g. parathion

or malathon, in the first half of the flight period of *Spil. ocellana,* about the time when the adult population of *Cac. podana* is at its highest.

This spray is mainly intended for the control of young larvae of *Cac. lecheana,* of young larvae of *Arg. variegana,* and of adult moths of *Cac. podana* and *Spil. ocellana.*

Spray no. 2. In late "high" summer. Any suitable insecticide, e.g., malathon or dimethyl-phosphonate (cf. p. 178), about two or three weeks after spray no. 1 (approx. when eggs of *Spil. ocellana,* laid at the time suitable for spray no. 1, are hatching).

This spray is mainly intended for the control of young larvae of *Pand. ribeana, Cac. podana* and *Spil. ocellana,* and of adult moths of *Spil. ocellana* and *Pand. heparana.*

Spray no. 3. In late summer. Any suitable insecticide, e.g. malathon or dimethyl-phosphonate, about five or six weeks after spray no. 1 (approx. when eggs of *Spil. ocellana,* laid at the time suitable for spray no. 2, are hatching).

This spray is mainly intended for the control of young larvae of *Spil. ocellana* and *Pand. heparana.*

Note: It is quite possible that all the above sprays are not equally necessary. Continued and extensive control experiments (tests of the efficiency of each of the three sprays) are much to be desired.

The advisory service has been largely based on observations on the seasonal appearance of the adults of *Cac. podana* and *Spil. ocellana.* As the seasonal appearance of the adults may alter considerably from one year to the next observations have (since 1951) been made annually.

Although valuable information about seasonal appearance may be gained from rearing experiments, such tests are laborious and for that reason not appropriate for yearly routine studies. During the last few years, therefore, the investigations on seasonal appearance have been chiefly founded on light trap experiments. A method for the use of the traps suitable for continued annual studies was developed. The main points of this method appear from the following.

The experiments discussed on p. 234 ff. show that under the conditions in Scania adults of *Cac. podana* and *Spil. ocellana* are attracted to artificial light (at least to light sources of the kind used in the traps at Åkarp) mostly in the middle part of the night. As far as these species are concerned, it is not rational, therefore, to operate the traps early or late in the night. In view of this the traps have in 1955—1957 (with the exception of trap A in 1956) been run solely between 11 p. m. and 1 a. m. On the whole, the catch results also from these latter years have given a sufficiently good idea of the flight period of the two moth species.

If a light trap is operated during the whole night the catch of insects often becomes overwhelmingly large and the sorting out of e.g. fruit leaf

tortricid specimens may take a lot of time. By using the trap only during the middle part of the night this trouble is of course largely eliminated.

An exposure period of not more than two hours per night is advantageous also from several other points of view. One and the same light bulb, for example, can be used in the trap during the whole summer without any risk of its capacity decreasing (during the period from the first to and including the last date of operation) by more than a few per cent (cf. p. 217).

In studying seasonal appearance by means of light traps attention must be paid to the fact that not only the alterations in the adult population but also the effect of the physical environment upon the behaviour of the insects cause fluctuations in the catch. Concerning the trap experiments at Åkarp, the fluctuations in the catch of *Spil. ocellana* were, as has already been stated, *largely* due to the influence of the physical environment upon the activity of the adult moths. As indicated by the analysis accounted for on p. 239 ff., wind velocity[1] and temperature were the most important physical factors from this point of view. The close concentration of the captures of *Spil. ocellana* to calm or only slightly windy periods has been discussed on p. 244 ff. The inhibiting effect of temperatures below 11 or 10 °C upon the flight activity of the same moth has been pointed out on p. 278 (cf. also p. 262). From the catch figures from Åkarp it might be suspected that the adults of *Cac. podana* are affected by physical environment, e.g. by wind velocity, in a similar way as the adults of *Spil. ocellana*.

By using a cup anemometer and a thermograph, satisfactory figures of wind velocity and temperature can of course be obtained. However, as the instruments require careful supervision, this method is circumstantial.

From the analysis dealt with on p. 239 ff. it can be concluded that adults of the *Psychodidae*, provided the temperature was above 10 or 11 °C, were caught in the light trap experiments at Åkarp (in summer) in large numbers almost always during calm periods. In contrast to this, psychodid specimens were in the same experiments seldom, if ever attracted to the light during windy periods, nor either during periods that were colder than 11 or 10 °C.

Regarding the trap experiments at Åkarp, it was found possible to use the catch of the *Psychodidae* as an indicator of the suitability of the weather for the catching of *Spil. ocellana*. For the period 11 p.m.—1 a.m. the following generalized schedule was prepared.

No. of psychodid specimens in catch	Suitability of weather for catching of *Spil. ocellana*
zero	unfavourable
1—9 10—99	doubtful
$\geq$ 100	favourable

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[1] The possible effect of the evaporative power of the air is not considered here (cf. p. 278).

Table 32. Number of specimens of Psychodidae, Cacoecia podana (♂) and Spilonota ocellana (♂) in trap A (Substation orchard, Åkarp) and in trap B (orchard at Alnarp), July 1—25, 1955—1957.

Note: In 1956 trap A was operated during the whole night. Otherwise the traps were, in 1955—1957, operated only from 11 p. m. to 1 a. m.

Night of	1955						1956						1957					
	Psychodidae		*Cac. podana*		*Spil. ocellana*		*Psychodidae*		*Cac. podana*		*Spil. ocellana*		*Psychodidae*		*Cac. podana*		*Spil. ocellana*	
	Trap		Trap		Trap		Trap		Trap		Trap		Trap		Trap		Trap	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
July 1	*	8	0	0	0	0	0	0	0	0	0	0	64	32	2	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	9	0	1	0	0
3	>200	74	0	0	0	0	>100	16	0	0	0	0	15	5	0	0	1	0
4	9	2	0	0	0	0	*	0	*	0	*	0	1	9	0	0	1	0
5	38	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	101	11	0	0	0	0	0	0	0	0	0	0	13	2	0	1	0	0
7	74	24	0	0	0	0	0	0	0	0	0	0	2	6	0	0	0	0
8	46	53	0	3	0	0	64	11	0	2	0	0	2	90	3	4	0	1
9	18	*	0	*	0	*	41	5	0	2	2	0	1	24	0	1	0	0
10	13	*	0	*	0	*	62	2	4	6	1	0	690	65	5	6	6	0
11	0	*	1	*	0	*	>100	9	3	3	3	1	1	0	0	1	1	0
12	*	16	*	5	*	0	>100	4	6	10	9	0	0	16	0	3	4	0
13	>200	>200	4	5	2	3	5	0	0	0	3	0	234	2	2	8	2	2
14	>200	>200	7	3	0	15	1	*	0	*	0	*	468	84	0	4	4	7
15	>200	>150	2	2	0	75	47	*	0	*	3	*	52	2	0	4	1	3
16	9	*	1	*	0	*	49	1	4	2	2	1	198	36	1	3	2	1
17	0	*	0	*	0	*	>100	4	3	4	9	0	410	54	0	0	6	0
18	>200	128	3	5	0	21	36	2	0	0	4	0	6	0	2	1	4	1
19	3	1	0	1	0	1	26	2	2	2	1	0	289	25	6	3	5	1
20	33	3	5	5	1	1	33	0	3	0	2	0	0	4	0	6	0	15
21	>200	>200	7	2	5	18	61	*	5	*	9	*	337	106	0	1	2	9
22	*	30	*	7	*	9	>100	*	0	*	5	*	387	141	1	3	3	6
23	7	*	1	*	0	*	0	0	0	0	0	2	0	0	0	1	0	2
24	40	*	3	*	4	*	2	0	0	0	2	1	0	0	0	0	0	0
25	143	59	11	1	0	30	0	0	0	0	0	0	84	21	0	0	3	1

* = Data missing

This schedule, of course, is arbitrary to some extent and may in some cases be misleading. On the whole, however, it has been of much help in connection with the advisory service work at Åkarp.

From the results of the light trap experiments it seems reasonable to assume that in the fruit tree districts in southern Sweden (e.g. in those mentioned in fig. 66 [p. 280]) the appropriate time for summer spray no. 1 (cf. spray schedule, p. 287) falls normally in the second week or round the middle of July (cf. table 29 [p. 285], fig. 50 [p. 254] and table 32). Sometimes, however, as shown by the experiments in 1953, the suitable time for this spray falls as early as late June (cf. fig. 51 [p. 255] and table 31 [p. 287]; see also fig. 20 [p. 192]).

The appropriate time for summer spray no. 2 may be estimated by determining the length of the incubation period of eggs of *Spil. ocellana,* laid at the time suitable for summer spray no. 1. Similarly, the appropriate time for summer spray no. 3 may be estimated by determining the length of the incubation period of eggs of *Spil. ocellana,* laid at the time suitable for summer spray no. 2 (cf. spray schedule, p. 288).

Under the conditions in Scania, as has already been stated (see p. 161), the eggs of *Spil. ocellana* take generally two à three weeks to hatch.

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